

Figure 13. Contour map of the perched water at the Test Reactor Area (November 2003 data).

3.3.1 Drilling and Well Completions

A well site geologist recorded the drilling and well completion activities as well as the lithology. The geologist collected specimens every 5 ft and at each observed change in lithology. The specimens were returned to the corresponding waste box at the completion of drilling.

Initial planning recommended that the wells should be located such that one well was “upgradient and one downgradient” of Well PW-13 and the diesel release site, as shown in the *Characterization Plan for Diesel Contamination in TRA Perched Water Well PW-13* (ICP 2004b). It should be noted that discussions of the perched-water gradient refer to relative elevations of the potentiometric surface of the perched water and the overall geometry of the perched-water system (Figure 13). Thus, a well downgradient of PW-13 would be located at a nearby location inferred to have a lower water-level elevation. Subsurface surveys conducted prior to drilling indicated that utilities and a building foundation were located at or near the intended locations. Potential alternate sites were evaluated with respect to structures, tanks, subsurface, utilities, overhead utilities, roadways, and potential impact on normal daily operations at the TRA facility. Two sites were selected, both within 250 ft of the believed diesel source and as close to the originally chosen locations as possible. Well TRA-1933 is located approximately 50 ft due west of PW-13; Well TRA-1934 is approximately 120 ft southwest of PW-13 (Figure 10). Both of these final locations provide “downgradient” monitoring relative to PW-13 and the diesel source. Potential upgradient locations would have been in close proximity to an existing well, USGS-053, and it was decided that a second downgradient well would be of greater benefit.

It should also be noted that the Characterization Plan (ICP 2004b) called for the wells to be completed as 2-in. polyvinyl chloride screens with a sand pack of 10 × 20 silica sand. Technical comments from project staff recommended the use of 4-in. stainless-steel casing and screen and 8 × 12 sand. The 4-in. stainless-steel casing and screen were used to simplify maintenance, increase the life of the well, and provide for easier sampling. The sand pack change was recommended to provide better flow into the well. The change in the sand pack may also prevent possible capillary exclusion of free-phase diesel, allowing more accurate observations of subsurface conditions. Cost increases resulting from the changes in materials were negligible, as was the additional waste generated from the increase in borehole diameter.

3.3.1.1 Well TRA-1933. Drilling of TRA-1933 was initiated on April 3, 2004. A small excavation approximately 1–2 ft deep was made by hand. The radiological control technician (RCT) performed a radiological survey of the excavated area and soil. No radiological contamination was noted. The 8-5/8-in. dual rotary (DR) casing was advanced approximately 7 ft bls before initiating air rotary drilling. Water was allowed to flow around the exterior of the casing from a garden hose, discharging 2 to 3 gpm. Bentonite was added as needed. Water discharge varied with the rate of casing advance and borehole conditions. Approximately 100 gal of water was discharged while setting the DR casing. Water approved for use during drilling was obtained from the coal-fired power plant at the Idaho Nuclear Technology and Engineering Center (INTEC).

The DR casing was advanced from 7 ft bls to basalt, located at 42 ft bls, using air rotary drilling in conjunction with the casing drive. The casing was advanced 8 ft into the basalt (50 ft bls). Drilling continued to a depth of 100 ft bls without further advancement of the casing. The perched-water zone was encountered at approximately 70 ft bls. A faint diesel odor was noted at 83 ft bls. A strong diesel odor and sheen were present on the cuttings throughout the remaining interval (83–100 ft bls).

After completion of drilling to 100 ft bls, an obstruction was found at a depth of 86 ft. The obstruction was drilled out and the hole advanced another 3 ft (to 103 ft bls) in order to provide space for sloughing material (basalt rubble) to accumulate and not interfere with well completion. The water level in TRA-1933 was measured several times before installation of the well and was determined to be stable at 70.1 ft bls. An interface probe was unable to measure the thickness of the floating diesel in the well. However, a video log of the hole that was completed before constructing the well showed a scum or sheen of floating diesel. The video log also confirmed the water-level measurement.

Well installation commenced on April 3, 2004. The well was installed with a 30-ft section of 4-in. stainless-steel, wire-wrapped, 0.020-in. slot screen from 90 to 60 ft bls. A 4-in. stainless-steel well casing was installed from the top of the screen to 2.5 ft above ground surface. A filter pack of 8 × 12 sand was installed from total depth to 54.1 ft bls. A bentonite seal was then installed from 54.1 to 20 ft bls. A 6-in. permanent protective surface casing was then installed from 20 ft bls to 3 ft above ground surface. Installation of bentonite continued until the annular spaces were filled with bentonite (Figure 14). The DR casing was removed during installation of the bentonite. Bentonite was kept inside the DR casing as it was removed. As the casing was removed, the bentonite inside the DR casing filled the annular space around the permanent well casing and prevented alluvium from caving in around the well casing, ensuring a complete seal.

Upon completion of the well on April 4, 2004, the drilling site was cleaned and the equipment demobilized to the Dynatec (subcontracted drilling company) laydown area east of INTEC. The equipment was surveyed by the onsite RCT before removal from the radiological buffer area; no radiological contamination was found and the equipment was approved for release from TRA.

A surface completion (including three impingement posts, cement surface pad, brass survey cap, and locking well cap) was installed on April 5, 2004. The USGS performed geophysical logging on May 3, 2004, recording natural gamma, gamma-gamma, and neutron logs of the well. Official well completion diagrams with lithology and geophysical logs are provided as supplemental information in Attachment 1 on the included data CD.

3.3.1.2 Well TRA-1934. Drilling of TRA-1934 was initiated on April 2, 2004. A small excavation approximately 1–2 ft deep was made by hand. The RCT performed a radiological survey of the excavated area and soil. No radiological contamination was noted. The 8-5/8-in. DR casing was advanced approximately 7 ft bls before initiating air rotary drilling. Water was allowed to flow around the exterior of the casing from a garden hose, discharging 2 to 3 gpm. Bentonite was added as needed. Discharge of water varied with the rate of casing advance and borehole conditions. Approximately 100 gal of water was discharged while setting the DR casing. Water approved for use during drilling was obtained from the coal-fired power plant at INTEC.

The DR casing was advanced from 7 ft bls to basalt, located at 56 ft bls, using air rotary drilling in conjunction with the casing drive. The casing was advanced 4 ft into basalt (60 ft bls). Drilling continued to a total depth of 100 ft bls. The perched-water zone was encountered at approximately 75 ft. The only indication of diesel was a faint odor noted at 90 ft bls. No subsurface difficulties were encountered during drilling.

Upon completion of drilling, the depth of the well was measured at 98 ft bls. The water level was measured several times before installation of the well and was determined to be stable at 75.4 ft bls. A video log of the hole showed a fractured vesicular zone at approximately 75 ft bls. A scum or sheen of diesel floating on the perched water also was noted in the video log. The water level was monitored after completion of the video log. The initial water-level measurement was 75.4 ft and the final measurement of 75.08 ft after the well was allowed to stand for over 1.5 hours.

The well was installed with a 30-ft section of 4-in. stainless-steel, wire-wrapped, 0.020-in. slot screen from 95 to 65 ft bls. A 4-in. stainless-steel well casing was installed from the top of the screen to 2.5 ft above ground surface. A filter pack of 8 × 12 sand was installed from total depth to 60.3 ft bls. The short distance between the top of the screen and the alluvium limited the sand pack above the screen to 4.7 ft in order to allow for an adequate seal between the alluvium and the sand pack. A bentonite seal was then installed from 60.3 to 20 ft bls. A 6-in. permanent protective surface casing was then installed from 20 ft bls to 3 ft above ground surface (Figure 15). The DR casing was removed during installation of the

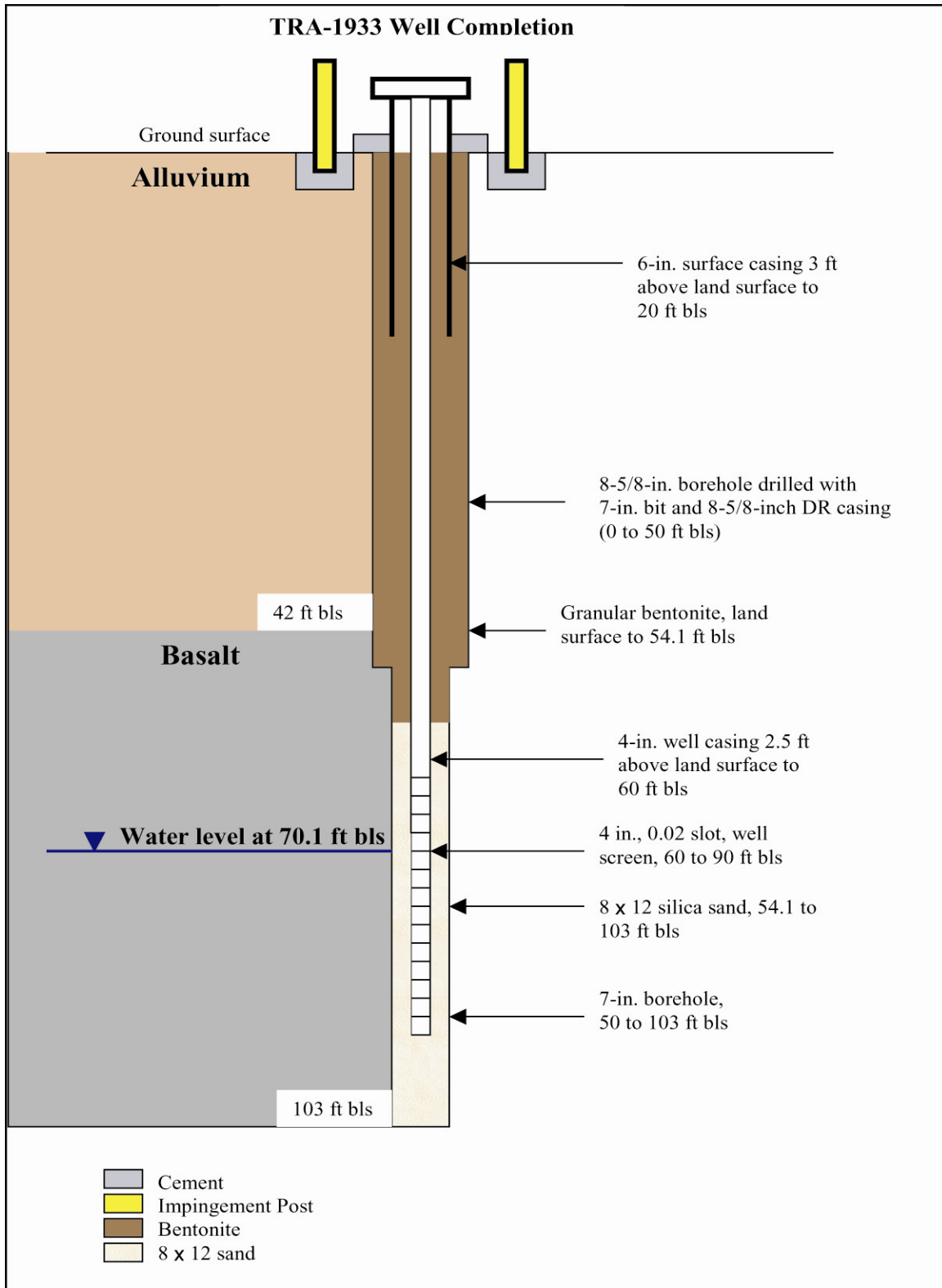


Figure 14. General completion diagram and lithology of TRA-1933 (not to scale).

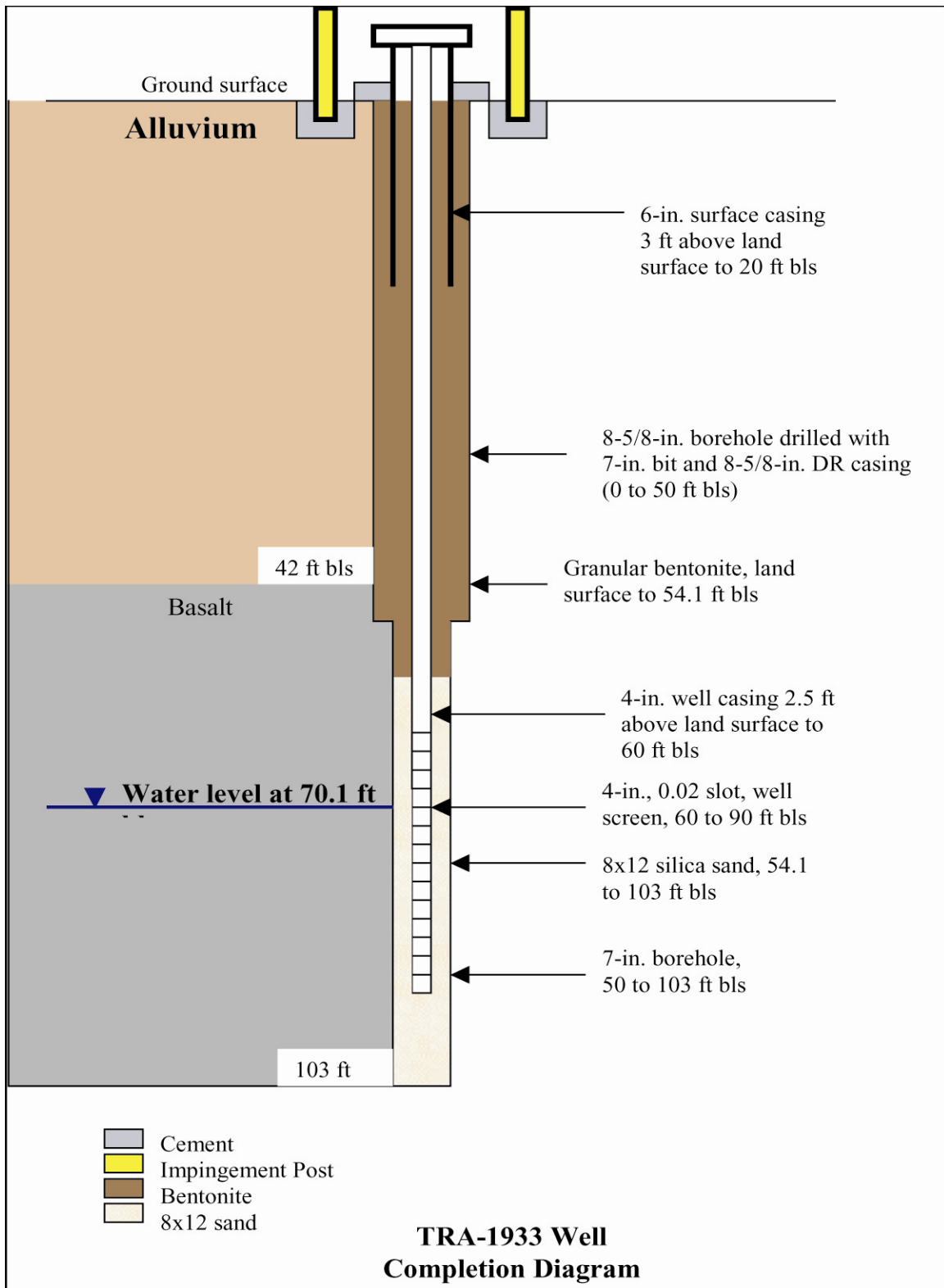


Figure 15. General completion diagram and lithology of TRA-1934 (not to scale).

bentonite. Bentonite was kept inside the DR casing as it was removed. As the casing was removed, the bentonite inside the DR casing filled the annular space around the permanent well casing and prevented alluvium from caving in around the well casing, thereby ensuring a complete seal.

Upon completion of the well on April 3, 2004, the drilling site was cleaned and the equipment was moved to the TRA-1933 site. The onsite RCT surveyed the equipment for contamination prior to moving to the new site and no radiological contamination was detected.

A surface completion (including three impingement posts, cement surface pad, brass survey cap, and locking well cap) was installed on April 5, 2004. The USGS performed geophysical logging on May 3, 2004, recording natural gamma, gamma-gamma, and neutron logs of the well. Official well completion diagrams with lithology and geophysical logs are provided as supplemental information in Attachment 1 on the included data CD.

3.4 Sampling and Analysis

Extent of the diesel contamination was investigated by sampling the two new wells (TRA-1933 and TRA-1934) and selected other wells for dissolved constituents of diesel fuel. Two downgradient aquifer wells (TRA-07 and USGS-076) were sampled to determine if diesel constituents had reached the aquifer. Four existing perched-water wells were selected to provide contaminant information up, down, and cross gradient with respect to the diesel release and PW-13 (Figure 13). Wells PW-10 (cross gradient), PW-12 (downgradient), USGS-053 (upgradient), and USGS-073 (cross gradient) were selected to constrain the lateral contamination, while Well PW-13 was selected for sampling to provide further analytical data regarding the diesel source and contaminant degradation.

Sampling of the existing perched water and aquifer wells was conducted in conjunction with the TRA quarterly groundwater-monitoring event in March 2004. Well PW-13 was sampled on March 17, 2004. Wells TRA-1933 and TRA-1934 were sampled on April 21, 2004. Existing wells were sampled in accordance with the *Groundwater Monitoring Plan for the Test Reactor Area Operable Unit 2-13* (DOE-ID 2004a). Wells TRA-1933 and TRA-1934 were sampled in accordance with the *Field Sampling Plan for the Characterization of the Diesel Contamination in the TRA Perched Water Well PW-13* (ICP 2004c). Wells TRA-1933, TRA-1934, and PW-13 were sampled for diesel-range organics (SW-846 8015A/B), gasoline-range organics (SW-846 8015B), and benzene, toluene, ethylbenzene, and xylene (BTEX) (SW-846 8021B) (EPA 2002). Well TRA-1934 also was selected for duplicate sampling for quality assurance purposes. Well PW-13 also was sampled for duplicate and replicate samples for gasoline-range organics and BTEX analysis. The remaining perched-water and aquifer wells were sampled for diesel-range organics (SW-846 8015A/B) (EPA 2002). Analytical results for the perched-water wells are compiled in Table 2. Note that the table included duplicates and replicate samples. More complete analytical data are provided in Attachment 2 on the included data CD.

3.4.1 Analytical Data from Selected Aquifer Wells

Diesel-range organic contaminants were not detected in either of the two sampled aquifer wells, TRA-07 and USGS-076. Both of these wells are located south of TRA and are downgradient of the source relative to the regional aquifer gradient (Figure 7). Well TRA-07 was selected for sampling because of its position relative to the diesel source and the regional aquifer flow. Based on the geometry of the perched-water system (Figure 13), the diesel contamination is believed to be migrating westward. The regional flow of the aquifer is south-southwest (DOE-ID 2003). Well TRA-07 is located downgradient to the southwest of the diesel source (Figure 10). Well USGS-076 is located almost directly south of the diesel release. This well was selected to provide a secondary data point and because of anecdotal reports of well-head odor. A visit to the well indicated that the odor likely was an environmentally friendly

lubricant, possibly used during the installation of the pump riser and water access line, rather than diesel. As with the other aquifer well, TRA-07, diesel-range organics were not detected at USGS-076.

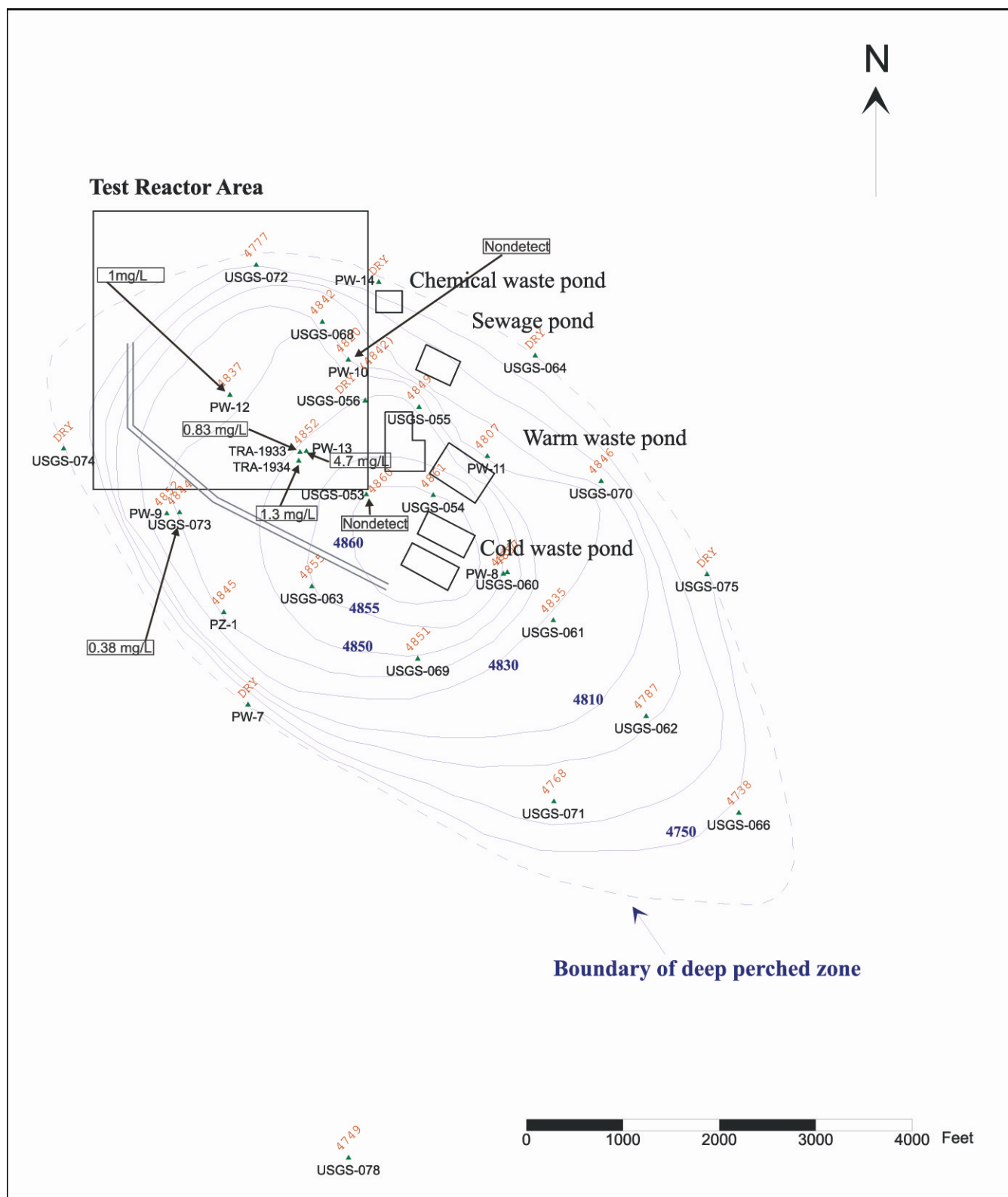
Table 2. Summary table of organics data from perched-water wells.

Well Name	Diesel-Range Organics	Gasoline-Range Organics	Benzene	Toluene	Ethylbenzene	Xylene (total)
PW-10	ND	—	—	—	—	—
PW-12	1 mg/L (J*)	—	—	—	—	—
PW-12	0.3 mg/L (J*)	—	—	—	—	—
PW-13	4.7 mg/L (J*)	309 µg/L	ND	ND	0.25 µg/L (J)	0.6 µg/L (J)
		87 µg/L	ND	ND	0.25 µg/L (J)	0.7 µg/L (J)
		86.3 µg/L	ND	ND	0.25 µg/L (J)	0.68 µg/L (J)
TRA-1933	0.83 mg/L	264 µg/L	ND	ND	2 µg/L	8.9 µg/L
TRA-1934 ^a	1.2 mg/L	206 µg/L	ND	ND	2.4 µg/L	2.5 µg/L
TRA-1934 ^a	1.3 mg/L	102 µg/L	ND	ND	3.6 µg/L	3.6 µg/L
USGS-053	ND	—	—	—	—	—
USGS-073	0.38 mg/L	—	—	—	—	—
<p>a. A duplicate sample was collected from TRA-1934 for quality purposes. — = not sampled J = Considered an estimate because of the uncertainty near reporting limit. J* = Hold time was exceeded. (NOTE: The PW-13 diesel-range organics sample also was flagged for high surrogate recovery.) ND = not detected TRA = Test Reactor Area USGS = United States Geological Survey</p>						

3.4.2 Analytical Data from Selected Perched-Water Wells

Sampling was conducted at existing perched-water wells (PW-10, PW-12, PW-13, USGS-053, and USGS-073) as well as at the two recently drilled perched-water wells (TRA-1933 and TRA-1934). Wells PW-13, TRA-1933, and TRA-1934 were sampled for diesel-range organics, gasoline-range organics, and BTEX, while the remaining perched-water wells were only analyzed for diesel-range organics.

Results (Table 2) indicated the presence of diesel-range organics in Wells PW-12, PW-13, TRA-1933, TRA-1934, and USGS-073. Diesel-range organics were detected in USGS-073 at a concentration of 0.38 mg/L (380 µg/L). The well is located to the southwest of the diesel release (Figure 16). Diesel-range organics also were detected in the PW-12 perched-water well, located northwest of the diesel release. However, the reported values of 1 mg/L (1,000 µg/L) and 0.3 mg/L (300 µg/L) received J flags. Diesel-range organics were not detected in samples from Wells PW-10 (located north of the diesel release) and USGS-053 (located southeast of the diesel release) (Figure 16).



The presence of diesel-range organics in Wells PW-12 and USGS-073 indicate that dissolved-phase diesel is migrating in the perched water. These two wells had not been previously sampled for diesel-range organics; therefore, it cannot be determined how long the contamination has been present or the rate of migration. Well PW-12 is downgradient of the diesel release site, based upon the overall geometry of the perched-water body. Well USGS-073 is cross- and slightly downgradient of the diesel release site. Analysis of perched-water data, discussed in Section 4, suggests that a previously unidentified source of water may be influencing the perched-water body beneath TRA. Data discussed in Section 4 identify several wells, including PW-13, as having geochemical signatures similar to aquifer water samples collected from the TRA-03 aquifer well, which is a TRA water supply well.

The similarity between the perched water at these locations and the water in the aquifer could indicate that water line(s) might be leaking. A leaking water line would not only influence the chemical signature of the water but the local hydrology as well. Thus, local flow paths may differ from those expected from the general shape of the perched-water body (Figure 16). (Note that the contour intervals in Figure 16 are irregular. Contour intervals are irregular for easier viewing.) Leaking water lines may account for the southwestward migration of the contaminants toward Well USGS-073 or the migration may simply be the result of the heterogeneous nature of the subsurface. It should also be noted that no free-phase diesel or diesel odor has been noted in either well, although Well PW-12 is not screened over the proper interval to allow free-phase diesel to enter the well. There is no direct evidence to indicate that the water lines may be leaking, but both potable and fire water lines pass within 20 ft of Well PW-13.

3.4.3 Analytical Data from Wells PW-13, TRA-1933, and TRA-1934

Samples collected from Wells PW-13, TRA-1933, and TRA-1934 were analyzed for diesel-range organics, gasoline-range organics, and BTEX (Table 2). Diesel-range organics were detected in all three wells. Well PW-13 contained a concentration of 4.7 mg/L, but the data were J flagged. Well TRA-1933 contained a diesel-range organic concentration of 0.83 mg/L. Although the odor and sheen of diesel were more noticeable in TRA-1933, a higher concentration of diesel-range organics, 1.2 and 1.3 mg/L, was measured in TRA-1934. Note that Well TRA-1934 was selected for duplicate sampling for quality assurance purposes and that two samples were collected from the well.

Gasoline-range organic constituents were detected in water from all three wells. Well PW-13 contained concentrations of 309, 87, and 86.3 µg/L. Comparing these three samples to the historical data presented in Section 3.2.2, the average gasoline-range organic concentrations within the well seem to be decreasing. Gasoline-range organic concentrations were reported at 264 µg/L in TRA-1933 and at 206 and 102 µg/L in TRA-1934.

Benzene and toluene were not detected in PW-13, TRA-1933, or TRA-1934. The lack of these common diesel-trace constituents support the hypothesis of an older, degraded diesel source. Ethylbenzene and xylene (total) were detected in all three wells. Three ethylbenzene samples were collected from PW-13 and the reported concentrations were 0.25 µg/L. The data were J flagged because of the uncertainty near the reporting limit. The previous sampling at PW-13 found no detectable concentration of ethylbenzene. An ethylbenzene concentration of 2 µg/L was reported for the sample collected from TRA-1933. Two samples were collected from TRA-1934 with reported values of 2.4 and 2.6 µg/L. Xylene (total) contamination also was detected in the three wells. Three samples collected from PW-13 contained concentrations of 0.6 to 0.7 µg/L, but the data were J flagged because of the uncertainty near the reporting limit. The reported values for Well PW-13 were lower than the single sample containing a detectable concentration of 2 µg/L, collected in June 2001. Wells TRA-1933 and TRA-1934 contained low concentrations of xylene with concentrations between 2.5 and 8.9 µg/L.

Concentrations of contaminants in PW-13 continue to decrease, possibly as a result of the degradation of the diesel. The single exception was a slight increase in the concentration of ethylbenzene in March 2004. The 0.25 µg/L of ethylbenzene was an increase from the nondetect recorded in June 2001. The previous detectable concentration was 0.2 µg/L, detected in November 2000. However, the increase in the reported value for March 2004 may be imprecise or inaccurate, as the reported value of 0.25 µg/L was J flagged, as was the previously detected concentration of 0.2 µg/L from November 2000. A geochemical analysis of the perched water (see Section 4) suggests that natural attenuation processes have removed the more soluble fraction of the diesel product, leaving behind the less soluble components as floating product.

3.5 Extent of Contamination

This section discusses the extent of the diesel contamination in the perched water. Diesel was not detected in the sampled aquifer wells. Diesel fuel can migrate laterally along the top of the perched-water body as a floating free phase, while dissolved constituents of the diesel fuel migrate within the water phase. The extent of contamination was defined in the Field Sampling Plan (ICP 2004c) as the lateral extent of contamination and the vertical thickness of the free-phase diesel. The lateral extent of contamination in the perched water and the vertical thickness of the free-phase diesel are discussed in Sections 3.5.1 and 3.5.2, respectively.

3.5.1 Lateral Extent of Diesel Contamination

Free-phase diesel was only discovered in the immediate vicinity of the 1981 release. As described in Section 3.5.2, the historical record shows the sporadic recurrence of free-phase diesel within Well PW-13. Small amounts of free-phase diesel also were noted during the drilling of TRA-1933 and TRA-1934. The minor amount of diesel encountered during the drilling of TRA-1934 may indicate that the well is near the outer extent of the free-phase diesel migration. Well TRA-1933 is closer to the source and showed a somewhat stronger presence of free-phase diesel during drilling activities. Neither free-phase diesel nor diesel odor was reported during the sampling of the other selected perched-water wells (PW-10, PW-12, USGS-053, and USGS-073). However, it should be noted that PW-12 is the only well not screened over the appropriate interval to allow free-phase diesel to enter the well at the current perched-water level. Based on these observances, it seems that the lateral extent of the free-phase diesel is limited to locations near the source (Figure 16). The lateral extent of the free-phase diesel is uncertain because of the limited data points available. However, continued monitoring of the wells exhibiting diesel contamination should provide information to constrain the lateral extent. Measurements of the diesel thickness were made using an interface probe at TRA-1933 and TRA-1934 during sampling, and no measurable thickness was present. Although the highly heterogeneous nature of this system precludes a complete understanding of the subsurface conditions, an adequate characterization of the subsurface can be completed.

Soluble constituents of the diesel enter the water phase through dissolution and degradation processes. These compounds, now in solution, will migrate with the water. The mobility of the dissolved-phase diesel in the subsurface is greater than that of the free-phase diesel and will result in wider migration of the dissolved-phase contaminants. As a result, the extent of the dissolved-phase constituents is considerably larger than the extent of the free-phase diesel. Consequently, it is not unusual to have detected diesel-range organics in a larger area than where free product is found. Diesel-range organics were detected in PW-12, PW-13, TRA-1933, TRA-1934, and USGS-073. Wells PW-10 and USGS-053 also were sampled for diesel-range organics, and results indicated no detectable concentrations. As shown in Figure 16, migration of the diesel has been westward toward Well PW-12 and USGS-073. Lack of detection at those wells could result from limited travel time, degradation, and dispersion of the soluble constituents within the perched-water body to below detectable levels; the

influence of heterogeneity; and the vertical component of the flow. Downward flow of the water, and consequently the dissolved-phase contaminants, may reduce the lateral extent of the dissolved-phase diesel contamination as contaminants infiltrate to depths greater than that of the well before migrating laterally into the well. As with the free-phase diesel, the heterogeneous nature of the vadose zone precludes a complete understanding of the lateral extent of dissolved-phase contamination; however, adequate characterizations can be made based upon analytical and hydrogeologic data.

Based upon the fluid properties of diesel, it is reasonable to believe that the extent of the free-phase diesel is significantly less than that of the dissolved-phase contaminants. Movement of diesel in the saturated zone will be controlled vertically by the presence of water and laterally by the physical characteristics of the subsurface and the moisture content. Undersaturated conditions, the migration of diesel will be limited because of the presence of the water. Water will preferentially flow through pore spaces around trapped diesel, preventing lateral and vertical migration. Physical characteristics also will limit diesel migration; fractures and dense basalt may hinder the lateral movement of diesel.

3.5.2 Vertical Thickness of Free-Phase Diesel

The field evidence indicates that the free-phase diesel floating on the perched-water body is relatively thin and discontinuous and it is likely that its extent could not be accurately determined unless many wells were drilled at close spacing. Free-phase diesel was encountered in Well PW-13 and during the drilling of Wells TRA-1933 and TRA-1934. In the former case (PW-13), diesel thickness is sporadic and highly variable (Figure 12). For the new wells (TRA-1933 and TRA-1934), small amounts of free-phase diesel were encountered while drilling below the surface of the perched-water body. After completion of drilling, only a thin sheen of diesel was found on the water surface with a thickness below the detection limit of the interface probe (1/100 ft). These limited data suggest that the free-phase diesel does not exist in a laterally extensive, thick layer. It is more likely that it is thin and fragmented. It should be noted that no free-phase diesel was noted above or at the surface of the perched water during the drilling of either TRA-1933 or TRA-1934, indicating an absence of floating free-phase product, at least at the time of drilling.

The presence of free-phase diesel at depths below the surface of the perched-water body might indicate that the diesel migrated into the drill holes from above the perched-water body during drilling activities in a manner similar to that believed to have occurred at PW-13. As an alternative, the free-phase diesel may have migrated into the areas of TRA-1933 and TRA-1934 during a period of lower water levels in the perched-water body. A subsequent rapid rise in the water level could have trapped the diesel beneath the current surface of the perched water in cavities and/or dead-end fractures. The diesel fuel also could have been forced below the water surface through an isolated vertical fracture when the leak occurred.

3.6 Controlling Mechanisms for the Recurrence of Diesel

The First Five-Year Review Report (DOE-ID 2003) identified the recurrence of free-phase diesel fuel in TRA Perched-Water Well PW-13 as an issue. The sporadic nature of that recurrence is atypical and warrants further discussion. Typically, one would expect that a single release of diesel fuel would produce a regular thickness of floating free phase that would decrease gradually in thickness with distance away from the source and also dissipate steadily with time. This investigation has shown that the free-phase diesel is not laterally or vertically extensive in the vicinity of Well PW-13 and that the presence of diesel in PW-13 is sporadic. This situation could be explained by either an intermittent source of diesel or a mechanism that moves a nonuniform thickness of free-phase diesel around in the subsurface.

Historical research and analytical data indicate that there is currently no ongoing source of diesel influencing the diesel levels in PW-13. Analysis of the diesel indicates that the diesel is degraded. The only known potential source is the abandoned transfer line, TRA-57, and testing of the line in 1990 did not reveal any leaks. The maximum potential volume of diesel that may remain in the transfer line is 310.5 gal and represents less than 16% of the total released volume. With no or minimal continued flux of diesel, the alternative explanation is that the diesel in the subsurface is being recycled by changing conditions. Several hypothetical mechanisms were developed and are presented below to illustrate how changing floating product thicknesses could be the result of natural conditions and not an indication of continued leakage. The hypothetical mechanisms are not tied to specific subsurface characterization, but are thought to be possible based upon the known subsurface conditions (i.e., a fractured, heterogeneous basalt aquifer with intermingled sediments and fluctuating water levels and flow conditions). Potential mechanisms are discussed in Sections 3.6.1, 3.6.2, 3.6.3, and 3.6.4.

3.6.1 Changing Flow Paths

Changing flow paths may move a finite volume of free-phase diesel from one location to another, taking it away from or bringing it to a well. The overall shape of the deep perched water at TRA is that of an elongated mound and appears relatively smooth at the scale of Figure 16. However, the highly heterogeneous nature of the geology may cause that mound to have local undulations that vary in size/shape with changes in recharge. Local flow paths will then vary with the size/shape of those undulations. Note that changes in recharge arise not only from discharge to the CWP, but may also be affected by natural recharge and irrigation (see Section 4). Free-phase diesel may become trapped in local depressions in the perched-water table and then move as the shape of the perched-water table changes. Figure 17 illustrates how local changes in the perched-water body could move a small body of floating free-phase diesel away from or to a well. Because such undulations in the surface of the perched-water body would be local in scale (i.e., not detectable in the overall geometry of the perched water), it may not be possible to determine if this is the mechanism for the recurrence. Chemical analysis of the perched water and its relation to the various sources may, however, provide some indication of local flow paths.

3.6.2 Changing Water Levels

Diesel trapped in the subsurface may be mobilized or remobilized by changing water levels. The flow system at TRA includes high-permeability fractures, interflows, and rubble zones that are separated from one another by the relatively impermeable basalt. The high-permeability features tend to have considerable storage capability but may not be well connected. In Figure 18a, free-phase diesel is trapped in fractures and a rubble zone, but cannot flow to the well. An increase in elevation of the perched water table allows the free-phase diesel to enter the well through the rubble zone (Figure 18b). Repeated rises and declines in the water table would lead to sporadic appearances of free-phase diesel in the well. The total volume of free-phase diesel would decline with time, leading to eventual cessation of this occurrence. Diesel fuel also could be released by a declining water table, as shown in Figure 19a, b. Note that these two geometric configurations (Figures 18 and 19) were developed as illustrative examples for the purpose of demonstrating the conceptual theory, not as a pictorial or schematic representation of actual subsurface conditions at this location. A wide variety of different geometries involving fractures of all orientations (i.e., vertical to horizontal), rubble zones, and interflows could trap and release diesel fuel with changing conditions in the perched-water table. Although the water levels and recurrence of diesel may be related, the regular fluctuations within the water level may make it difficult to verify. Continued routine measurements in PW-13, as well as in TRA-1933 and TRA-1934, could provide the necessary information to make this determination.

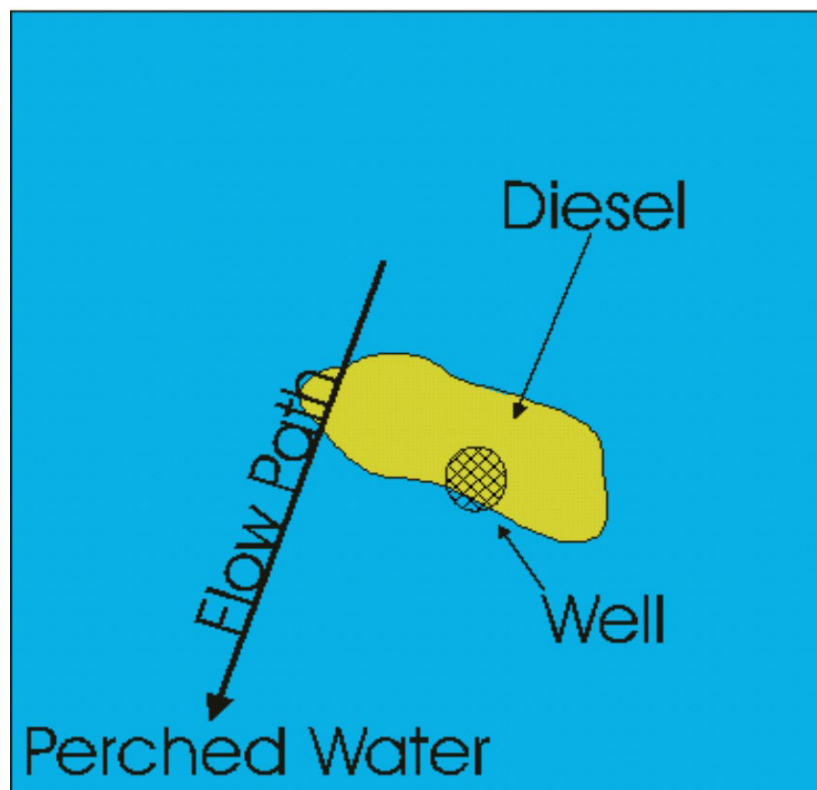
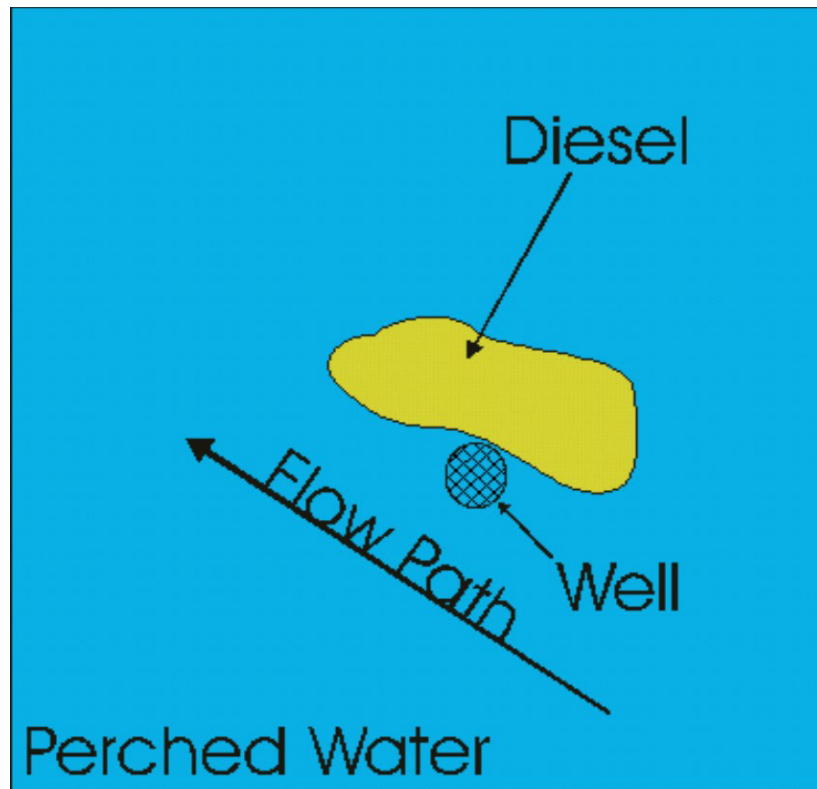


Figure 17. Diesel migration influenced by a changing flow path.

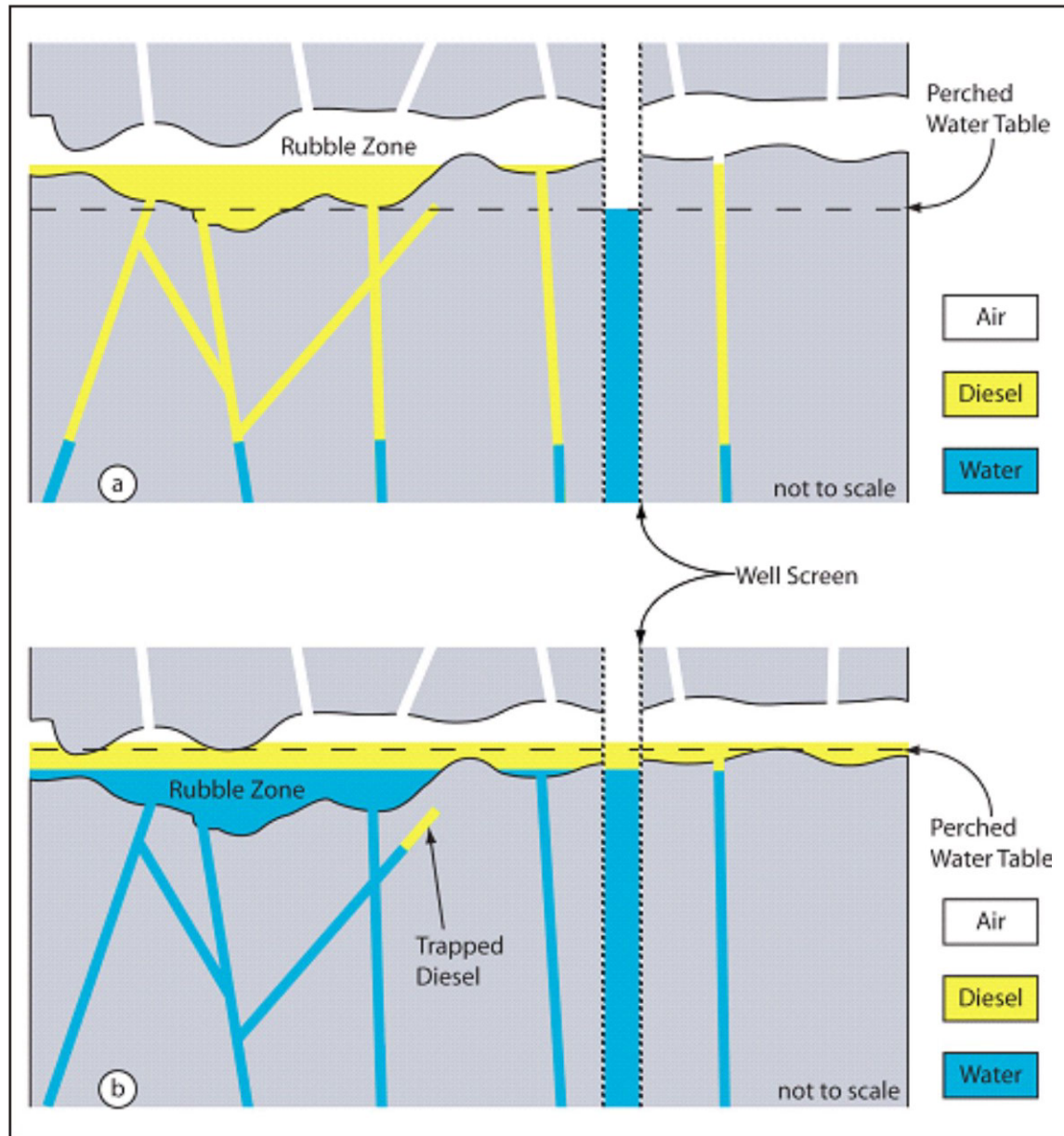


Figure 18. Remobilization of diesel resulting from an increase in water level.

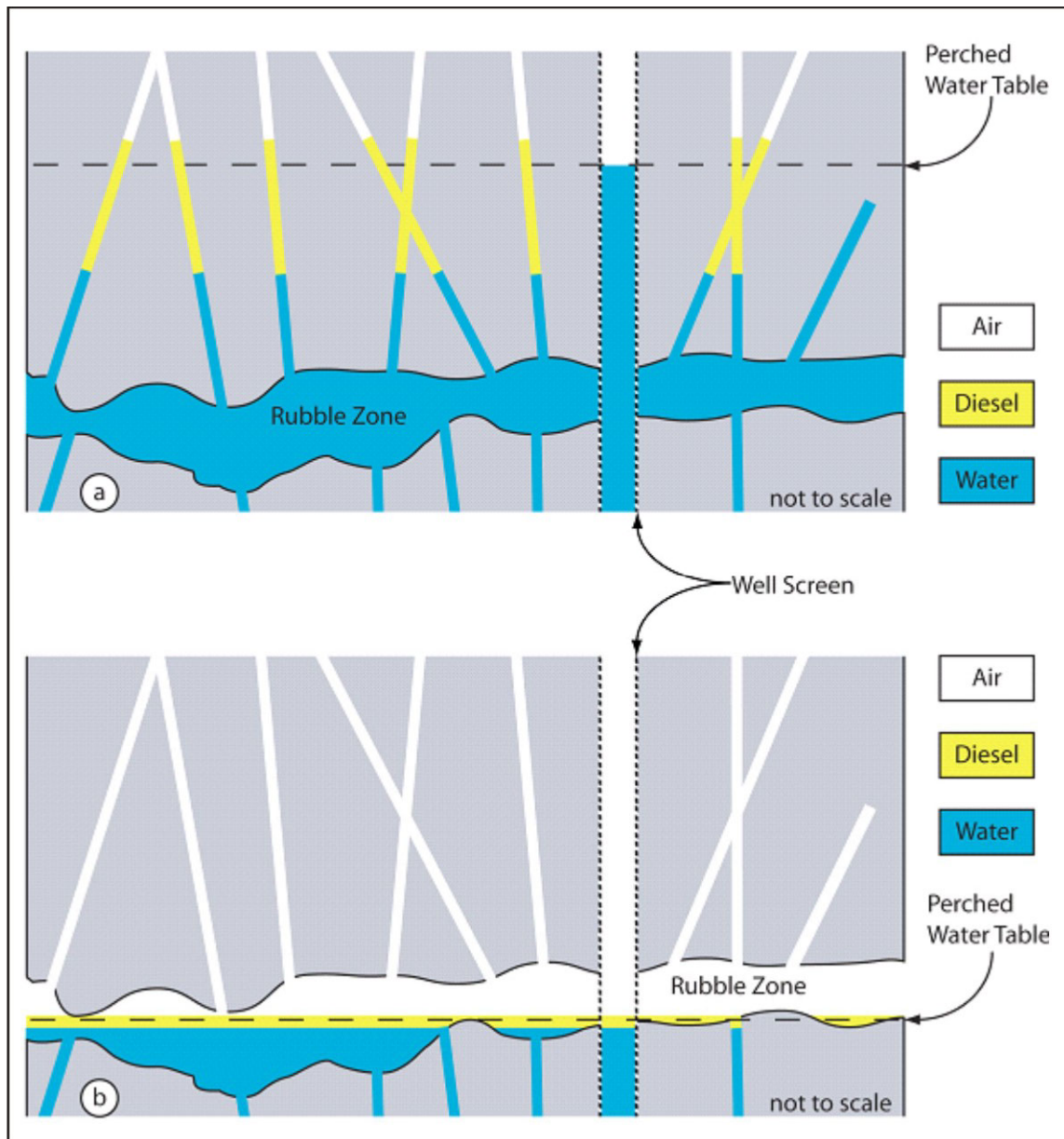


Figure 19. Remobilization of diesel resulting from a decrease in water level.

3.6.3 Pulsed Flux

Migration of diesel into the well could result from pulsed flux of diesel from above the perched-water body. Diesel fuel that leaked from TRA-57 may have pooled in various locations above the perched-water body. Potential locations for such pools include dead-end fractures, rubble zones, and at the alluvium-basalt interface. Few fractures extend vertically through the dense, massive interior of a basalt flow; hence, pools above the perched water may be poorly connected in the vertical direction. The pooled diesel may be periodically mobilized by transient conditions in the subsurface. Figure 20 provides an illustrative example of diesel fuel pooled on top of a small perched-water body located in sediments above the alluvium-basalt interface. Please note that Figure 20 is provided as an illustrative example for demonstrating a conceptual theory, not as a pictorial representation of actual subsurface conditions.

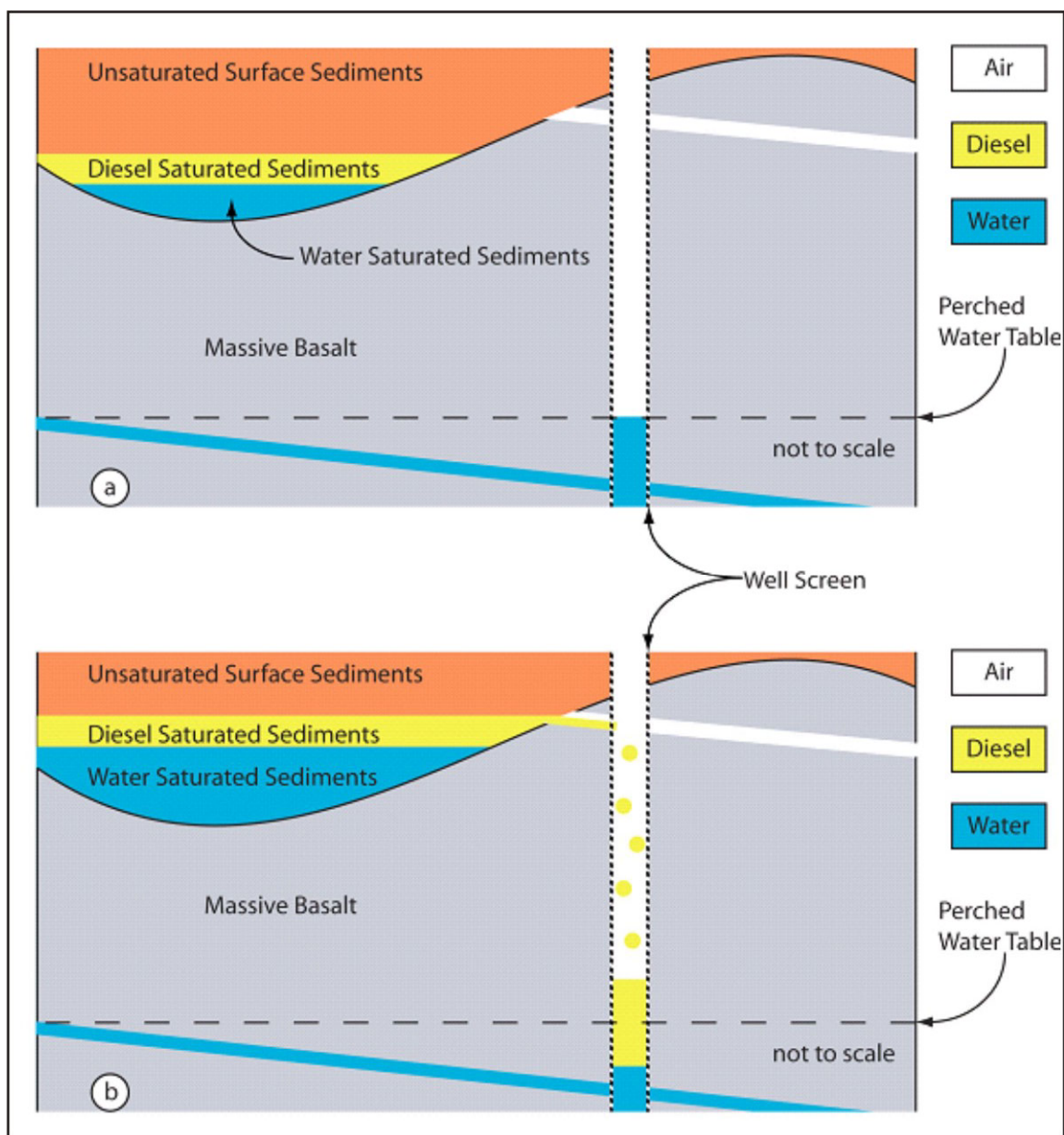


Figure 20. Pulsed flux of diesel from an overlying local perched-water body.

The low permeability of the basalt restricts downward migration, trapping the diesel above a shrinking water pool (Figure 20a). Subsequent addition of water (recharge) raises the diesel fuel to connect with a fracture that intersects the well (Figure 20b). The example shown in Figure 20 is just one of many geometric configurations that could lead to pulsed flow. Other configurations could carry diesel directly to the perched-water body, rather than to the well. However, note that the configuration shown in Figure 20 would produce a substantial thickness of diesel within the well alone. Free-phase diesel would not spread from the well; instead, it would dissipate through dissolution into the perched-water body. This scenario is consistent with observations at Well PW-13. In addition, there could be multiple pools of diesel above the perched-water body with individual pools pulsing at different times or possibly cascading vertically from one pool to the next. Changes in the subsurface distribution of diesel fuel could result from a leak in the nearby raw water line. Although there is no evidence that the line is leaking, the chemical signature of the water at PW-13 seems to indicate the possibility, as discussed in Section 3.6.4.

3.6.4 Continued Flux

Although it is highly unlikely that the diesel recurrence in PW-13 is from an ongoing leak, the recurrence could be attributed to continued flux from the original source. The original entry of diesel fuel into PW-13 during the 1990 coring operation is believed to have occurred at 47 ft bls, well above the perched-water body. The next reported occurrence of free-phase diesel in PW-13 was 9 years later in November 1999. This timeline would be consistent with an unusually slow migration through the unsaturated zone. In effect, the original diesel release may be moving slowly downwards to the perched-water body and having fragmented along the way is arriving at discrete intervals. Slow migration of the diesel could be the result of transient conditions (such as moisture content in the unsaturated zone or flow paths of different lengths). During wetter periods, the diesel migration could be slowed or even halted by an increased moisture content, as water moves into large pores that would normally be open to the flow of a non-wetting fluid (such as air or diesel fuel). This situation can occur during periods of infiltration because of spring melts or leaking water pipes. The transient conditions might have caused the continued flux of diesel from the original source to appear irregular and/or pulsed.

3.7 Summary of Findings

Although the diesel fuel found in Well PW-13 was apparently released to the subsurface over 20 years ago, no diesel contamination has been detected in aquifer wells, although only limited sampling (TRA-07 and USGS-076) has been conducted. Under saturated conditions, water will migrate preferentially through pore spaces, restricting and trapping free-phase diesel. Further, the less dense diesel will also float or pool on water, effectively prohibiting the downward migration of diesel in a free-phase state, if the perched water zone is laterally continuous. The physical properties and interaction of water and diesel, coupled with the limited analytical data, suggest that the diesel fuel likely is trapped in the perched-water zone above the regional aquifer. The perched-water body currently serves to limit the downward migration of the free-phase diesel, while providing an opportunity for the diesel fuel to degrade and disperse. Although no contamination—free phase or dissolved—has been noted in the aquifer, it should be noted that there is only limited analytical data and a limited number of aquifer wells downgradient of TRA, and dependent upon the actual local conditions of the aquifer, the existing wells might not be sufficient to capture contamination resulting from the diesel release. Vertical migration of free-phase product also could occur along the margins of the perched-water body or even within the areal extent of perched-water body if the saturated zone is not laterally continuous.

Analytical data obtained during this investigation indicate an older source for the diesel contamination that has degraded while in contact with the perched-water body. These data support historical data collected after the discovery of diesel during the drilling of PW-13. The data cannot rule out a continued flux of degraded diesel from the original source (TRA-57). However, the line was tested

in 1990 and the results indicated no leaks in the line. The No Further Action determination for the TRA-57 fuel line was based upon a release of 2,000 gal, which included the maximum volume (310.5 gal) that the fuel transfer line could contain. The risk assessment completed during the Track 1 showed that the 2,000 gal of diesel fuel entering the aquifer did not pose a risk. Consequently, any fuel that might have remained in the transfer line and has begun to leak since the 1990 test has been accounted for during the Track 1 risk assessment and accounts for less than 16% of the total volume released.

Information obtained from both drilling and sampling did not provide evidence to dispute the calculated volume of 2,000 gal. Although diesel was encountered during the drilling of both TRA-1933 and TRA-1934 and dissolved-phase diesel was detected in the PW-12 and USGS-073 perched-water wells, the heterogeneous nature of the TRA subsurface can allow for wide spreading along preferential flow paths (such as fractures or interflow zones).

With no sources of diesel within 1,800 ft of PW-13, and analytical data indicating a degraded diesel, the recurrence of diesel within PW-13 seems to be the result of periodic remobilization of diesel in the subsurface. The diesel contained with traps and fractures is periodically remobilized, entering the well during changes in subsurface conditions and likely being returned to the fractures and traps when the conditions change again. The diesel could be cycled repeatedly over time, but always decreasing in total volume.

The diesel encountered beneath the surface of the perched water might indicate that the diesel migrated into the areas of TRA-1933 and TRA-1934 during a period or periods of lower water levels. The absence of diesel floating on the perched water during drilling at these locations might indicate that the free-phase diesel that migrated into these areas is now trapped within the perched-water zone, restricting further migration of the free-phase diesel, but also potentially increasing the rate of dissolution because of the greater surface area in contact with the perched water. However, it is also possible that the diesel encountered beneath the surface of the perched water is the result of injection of diesel because of differences in pressure head or it could be the result of diesel draining into the borehole during drilling. An injection of diesel below the subsurface could occur if a significant difference in head existed. If free-phase diesel pooled in a fracture above and connected to the perched water, continued accumulation could create a difference in pressure heads, allowing the diesel to inject into the perched water (i.e., the pressure head of the diesel is greater than the pressure head of the water).

Natural attenuation processes likely are impacting the dissolved-phase hydrocarbons. As a result, the residual floating petroleum product might contain a high percentage of less easily degradable petroleum hydrocarbons that are more resistant to natural attenuation processes. The highly variable occurrence of floating product in PW-13 would favor passive recovery of the petroleum product.

Data and information collected during this investigation indicate that the No Further Action determination listed in the OU 2-13 ROD (DOE-ID 1997a) is currently protective of human health and the environment.

3.8 Recommendations

Because of the sporadic and inconsistent behavior of the diesel recurrence, further monitoring is recommended. Additional routine monitoring is recommended to document any further migration of diesel and ensure that the No Further Action determination remains valid. Suggested monitoring activities are listed below:

- Installation of petroleum traps in Wells PW-13, TRA-1933, and TRA-1934. The traps will allow the volume of diesel to be measured and will provide an inexpensive, passive means for the

removal of old diesel and collection of samples for analyses to determine if new diesel is entering the subsurface. Petroleum traps (Figure 21) consist of a hydrophobic filter attached to a float. The float keeps the filter above the water level, allowing diesel to enter the filter. The diesel is collected in a collection canister, which can be drained during maintenance.

- Monthly water-level and diesel thickness measurements at Wells PW-13, TRA-1933, and TRA-1934.
- Monthly maintenance of the petroleum traps performed in conjunction with water-level and diesel thickness measurements (see note below).
- Periodic monitoring of selected perched-water wells or aquifer wells may be warranted, but it is recommended that they occur no more frequently than annually, unless monitoring results dictate otherwise. It is recommended that Well PW-12 have diesel-range organics added to the analyte list and that USGS-073, TRA-1933, and TRA-1934 be added to the Waste Area Group 2 groundwater monitoring plan for diesel-range organics analysis. It is also recommended that at least one sample of the free-phase product be collected and analyzed to determine the extent of degradation. The free-phase sample will be used to determine the degradation state of the diesel. The sample is recommended as a one-time event unless the sample indicates a nondegraded source.

NOTE: *The use of petroleum traps may complicate the measurement of diesel thicknesses. If petroleum traps are installed, it is recommended that they be removed during the monthly maintenance and the volume contained in the trap measured. The water level and remaining diesel thickness, if any, should be measured before reinstalling the trap. The volume of the diesel in the trap should then be converted to a thickness and added to the measured diesel thickness in order to obtain a complete diesel thickness measurement. Any diesel remaining in the borehole should then be removed by reinstalling and removing the trap or by bailing.*

4. GEOCHEMICAL EVALUATION OF PERCHED-WATER CONTAMINATION AND WATER SOURCES

The First Five-Year Review Report (DOE-ID 2003) recommended that a geochemical investigation be performed to “fingerprint” various water sources at TRA and correlate sources to water in the perched-water wells. This section presents sampling results from March 2004 and then discusses the sources of perched water and contaminants in the perched water. The flux of contaminants from the vadose zone into the aquifer also is examined. Identification of water sources responsible for the perched-water bodies is essential for modeling and remediating contamination because water sources provide the medium for transporting contaminants to the perched-water bodies and eventually to the aquifer. Historical data also are used to evaluate the sources of perched water and contamination. The goals of the geochemical evaluation are as follows:

- Examine the distribution of contaminants in the perched water to determine sources of contaminants
- Characterize water sources based on major-ion chemistry and oxygen- and hydrogen-isotope data to determine water sources
- Evaluate flow paths using oxygen- and hydrogen-isotope data and major-ion chemistry data
- Combine information on contaminant sources and water sources to characterize perched-water bodies.

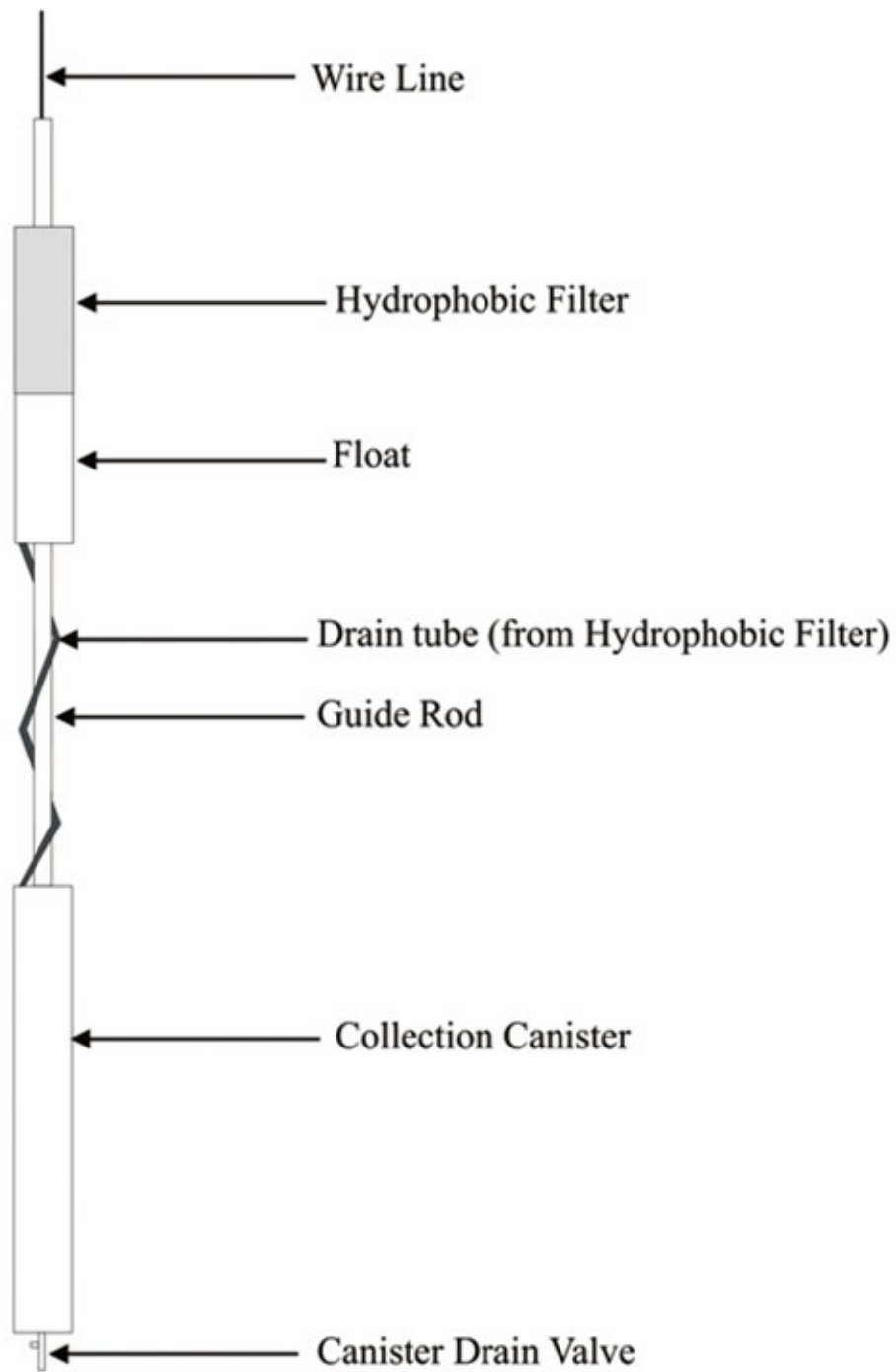


Figure 21. Simple illustration of a petroleum trap.

Groundwater samples were collected from the perched-water wells and aquifer wells that are listed in Table 3. Samples were not collected from the PW-14 and USGS-056 perched-water wells, because they were dry at the time of sampling. Perched-water samples were analyzed for metals, Sr-90, tritium, anions, and gamma-emitting isotopes. Seven wells also were sampled for organics to evaluate the extent of petroleum contamination near Well PW-13. When radiological results are reported in the text of this document, only the concentrations are given; the associated analytical uncertainties are listed in Table 3 and are provided in Attachment 2 on the supplemental data CD. The minimum detectable activity for each sample is included in Attachment 2, and complete data from the water sampling conducted in March 2004 also are provided in Attachment 2.

4.1 Perched-Water Contaminant Data

Extensive perched-water sampling and analysis were conducted on TRA wells during March 2004 as part of this investigation and in coordination with regular Waste Area Group 2 sampling activities. Table 3 summarizes the primary radiological (Co-60, Sr-90, and tritium), anion (sulfate), and metals (chromium) contaminant data. Sample concentrations are compared with MCLs. However, these comparisons are not intended to imply that the perched-water bodies represent an aquifer capable of long-term use or as a potable water source.

Metals samples were filtered to provide a representative and consistent data set for the geochemical analysis. Although, small colloidal particles can still get through the 0.45- μ m filters, the filtered fraction more closely represents the fraction of metals that are dissolved and therefore more mobile and representative of geochemical processes. Unfiltered samples were not used for the geochemical analysis because the chemistry of perched-water samples can be greatly altered when the acid used to preserve the sample is added because perched-water samples contain varying amounts of suspended solids. In unfiltered samples, the dissolved metals fraction or naturally mobilized fraction cannot be separated from the metals fraction that is mobilized by the acid added to preserve the sample. In order to avoid the uncertainties associated with using unfiltered data, the filtered metals data were used to determine sources of water and to evaluate geochemical processes, because a representative and comparable data set was needed.

4.1.1 Chromium

Chromium analytical results from the perched-water wells were below the EPA-defined MCL of 100 μ g/L during the March 2004 sampling event for filtered samples. Figure 22 shows filtered chromium concentrations in the perched-water wells from March 2004. The highest filtered concentration was in PW-10 at 76.9 μ g/L. The highest chromium concentrations are northwest of the CWP near the former WWP and Warm Waste Retention Basins and the former Chemical Waste Pond. In addition to the main area of elevated chromium concentrations, chromium was present in Wells USGS-073 (33.1 μ g/L) and USGS-066 (28.6 μ g/L). The chromium results are for total chromium. The assumption is made that most of the chromium would be in hexavalent form under oxidizing conditions present in the perched water at locations other than PW-13, TRA-1933, and TRA-1934.

4.1.2 Cobalt-60

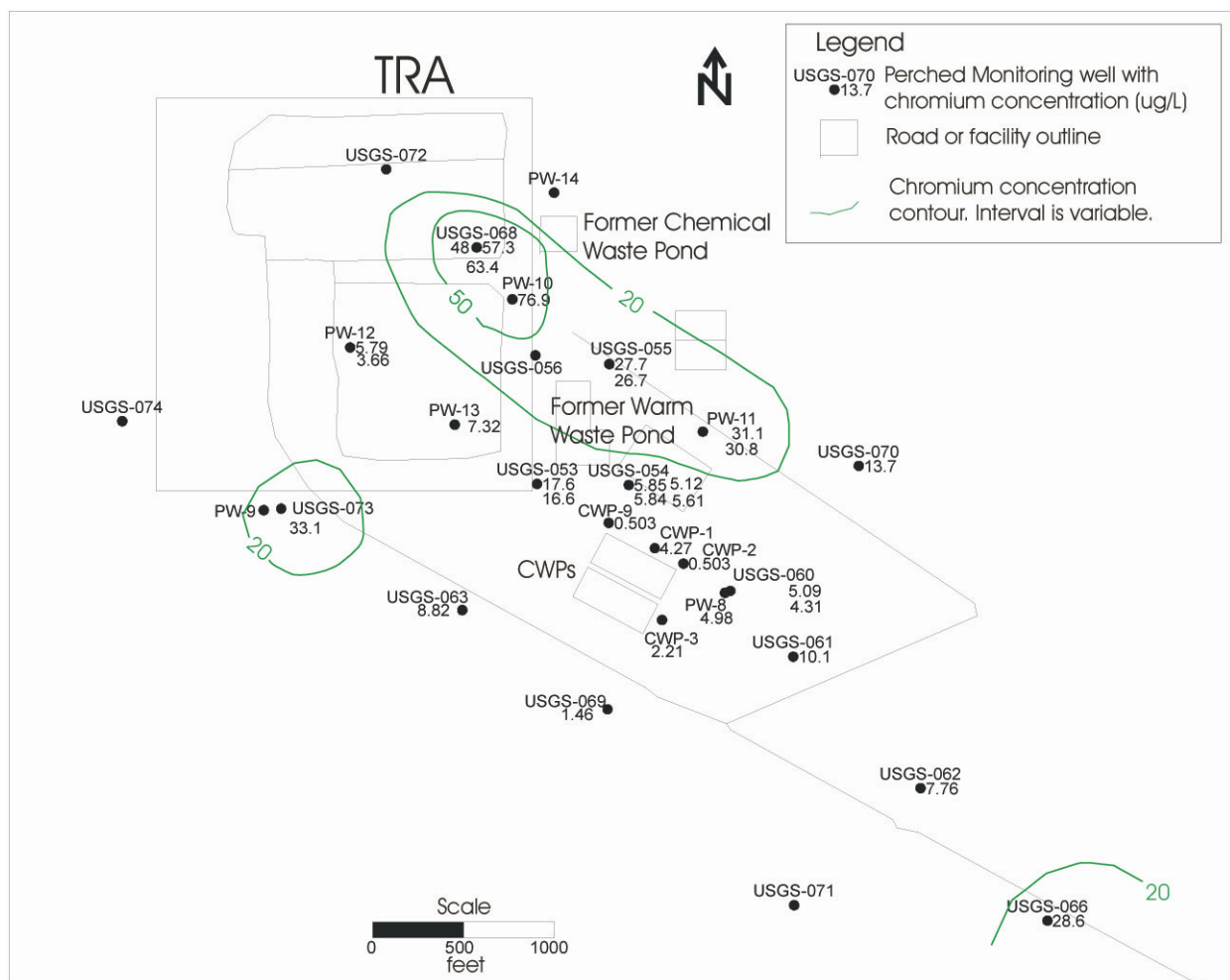
Cobalt-60 was detected in Well PW-12 at a concentration of 52.7 pCi/L in March 2004. Cobalt-60 was not present at detectable concentrations in any of the other wells. The concentration level found at PW-12 is below the EPA-defined MCL of 200 pCi/L for Co-60. The Co-60 concentration in PW-12 has declined considerably from the result in March 2003 of 330 pCi/L (ICP 2004d).

Table 3. Summary of select analytes for samples collected in March 2004.

Well	Depth	Cobalt-60			Strontium-90			Tritium			Sulfate	Chromium (filtered)		Chromium (unfiltered)				
		pCi/L	+/-	Flag	pCi/L	+/-	Flag	pCi/L	+/-	Flag	mg/L	Flag	ug/L	Flag	ug/L	Flag		
<i>Perched-Water Wells</i>																		
CWP-1	48.45–59.44	0.00552	1.96	U	0.0519	0.106	U	-29	78.4	U	283	—	4.27	B	U	8.26	B	—
CWP-2	45.95–52	— ^a	—	—	—	—	—	—	—	—	95.8	—	0.503	U	—	—	—	—
CWP-3	50.16–57	0.0744	1.58	U	5.9	0.876	—	0	82.3	U	58.4	—	2.21	B	U	7.55	B	—
CWP-9	34.3–64.45	0.362	1.33	U	91.1	12.8	—	293	91.7	—	0	U	0.503	U	—	2.46	B	—
PW-10	103.02	4.98	2.76	U	0.981	0.186	—	8,200	256	—	258	—	76.9	—	—	79.7	—	—
PW-11	109.75	4.61	2.87	U	0.975	0.214	—	37,700	643	—	162	—	30.8	—	—	32.7	—	—
PW-12	85.4	52.7	6.03	—	67.7	8.62	—	1,610	146	—	23.6	—	5.79	B	U	19.1	—	—
PW-13	71.52–89.97	1.7	3.11	U	14	1.88	—	-92.7	81.1	U	20.2	—	7.32	B	U	3.63	B	—
PW-8	69.55	0.314	1.42	U	5.65	0.831	—	167	82.9	UJ	127	—	4.98	B	U	6.2	B	—
USGS-053	70.03	0.14	4.35	U	48	6.2	—	3,620	191	—	98.4	—	16.6	—	—	18.5	—	—
USGS-054	66.01	0.651	1.83	U	48.6	7	—	247	88.5	UJ	101	—	5.12	B	U	6	B	—
USGS-054	66.01	-1.19	2.04	U	48.6	6.48	—	122	87	U	100	—	5.84	B	—	5.57	B	—
USGS-055	62.1	5.08	1.82	UJ	42.5	5.59	—	13,000	231	—	94.1	—	26.7	—	—	31.6	—	—
USGS-060	68.58	1.63	1.82	U	0.695	0.159	J	-91.6	80.1	U	98.4	—	4.31	B	U	4.27	B	—
USGS-060	68.58	-0.733	2.01	U	0.372	0.123	UJ	-57	76.1	U	102	—	5.09	B	U	4.37	B	—
USGS-061	90.27	2.82	1.36	UJ	0.179	0.129	U	2,580	152	—	140	—	10.1	—	—	12.7	—	—
USGS-062	136.57	3.05	1.42	UJ	1.44	0.257	—	147	86.7	U	142	—	7.76	B	—	6.53	B	—
USGS-063	76.05	3.09	2.26	U	1.26	0.228	—	30.9	86.2	U	133	—	8.82	B	—	9.97	B	—
USGS-066	183.9	-0.00969	2.02	U	-0.00371	0.101	U	1,230	126	—	155	—	28.6	—	—	539	—	—
USGS-068	83.74	-1.11	1.83	U	0.421	0.129	UJ	0	84.3	U	1,100	—	48	—	—	77.8	—	—
USGS-068	83.74	2.67	1.9	U	0.239	0.116	UJ	29.2	81.4	U	1,220	—	63.4	—	—	74.8	—	—
USGS-069	79.45	2.14	1.77	U	-0.0979	0.122	U	-30.3	82.1	U	87.5	—	1.46	B	U	11.1	—	—
USGS-070	72.86	3.75	2.31	U	33.1	4.18	—	2,850	157	—	106	—	13.7	—	—	13.2	—	—
USGS-073	87.48	10.4	5.95	U	0.518	0.151	U	10,500	291	—	89.5	—	33.1	—	—	150	—	—
<i>Aquifer Wells</i>																		
TRA-03	—	—	—	—	—	—	—	—	—	—	23.6	—	3.13	B	U	—	—	—
TRA-06	479.6	0.0416	3.89	U	0.272	0.185	U	2,400	171	—	— ^b	—	8.32	B	—	8.37	B	—
TRA-07	485.32	0.449	1.97	U	0.0748	0.154	U	18,800	447	—	99.8 ^c	—	131	—	—	146	—	—
TRA-08	489.5	-0.56	1.65	U	0.272	0.15	U	4,450	218	—	51.9	—	33.1	—	—	40.2	—	—
USGS-058	503	-0.517	1.76	U	-0.177	0.179	U	1,910	151	—	32.8	—	15.5	—	—	15.6	—	—

Table 3. (continued).

Well	Depth	Cobalt-60			Strontium-90			Tritium			Sulfate		Chromium (filtered)		Chromium (unfiltered)			
		pCi/L	+/-	Flag	pCi/L	+/-	Flag	pCi/L	+/-	Flag	mg/L	Flag	ug/L	Flag	ug/L	Flag		
USGS-065	467.55	0.0304	1.81	U	0.127	0.144	U	8,610	298	—	— ^b	—	109	—	—	107	—	—
MIDDLE-1823	493.04	2.69	1.63	U	-0.0749	0.176	U	2,260	163	—	—	—	6.44	B	J	12.1	—	J
HWY-3	750	5.03	2.18	UJ	0.171	0.16	U	169	96.3	U	— ^b	—	1.43	U	—	1.43	U	—
USGS-076	489.29	—	—	—	—	—	—	—	—	—	30.6	—	11.3	—	U	—	—	—
CWP = Cold Waste Pond TRA = Test Reactor Area USGS = United States Geological Survey																		



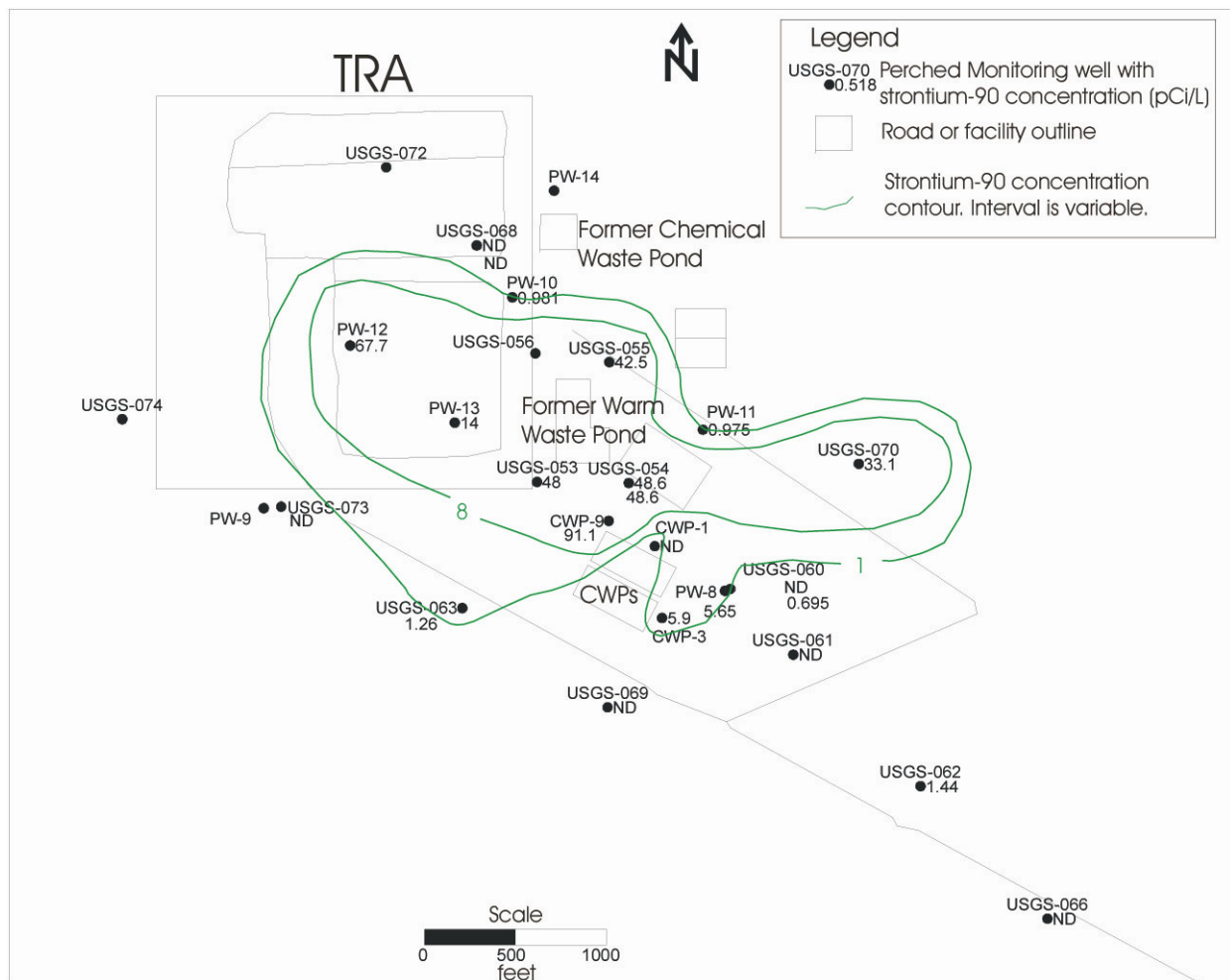


Figure 23. Distribution of strontium-90 in perched water in March 2004.

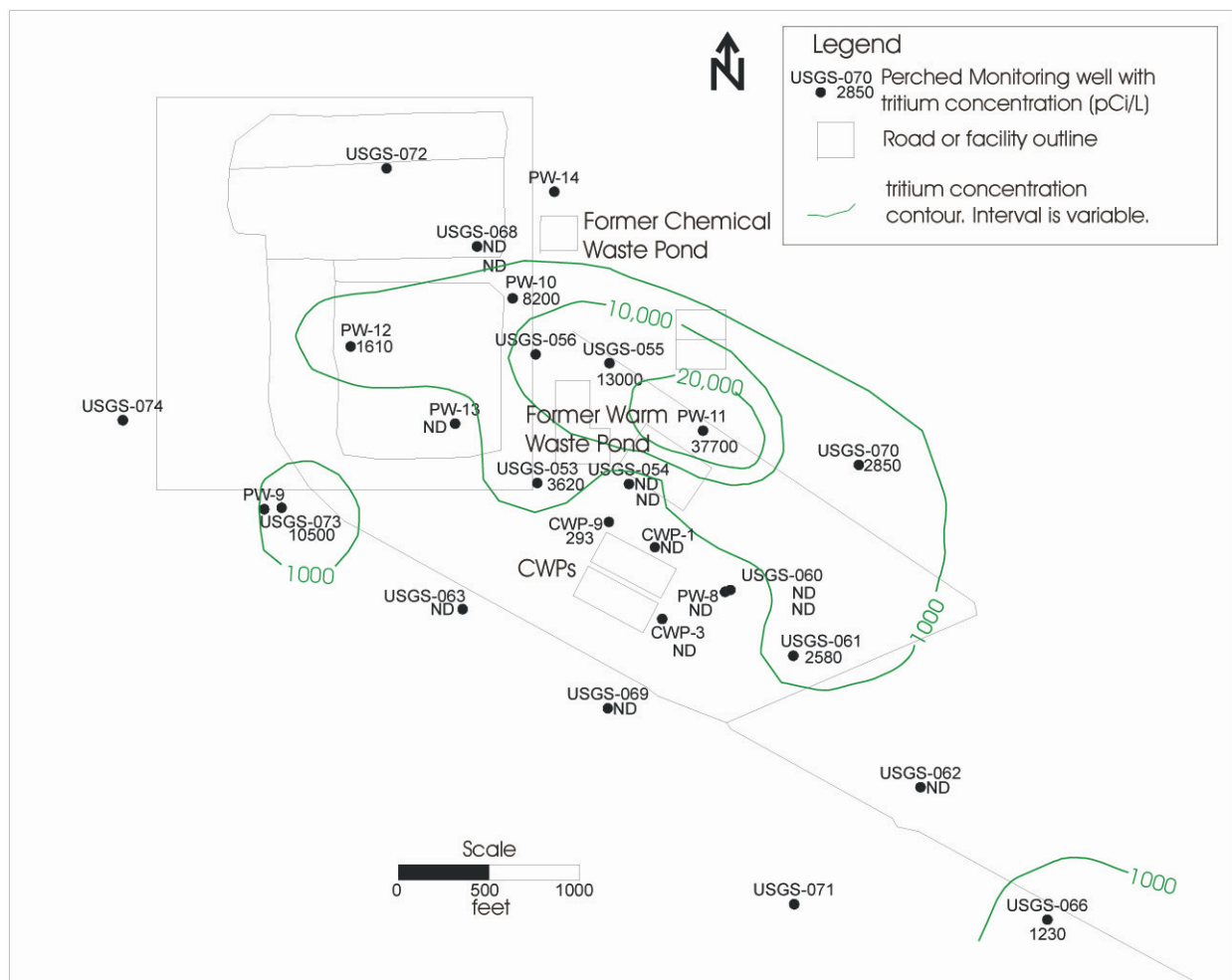


Figure 24. Distribution of tritium in perched water in March 2004.

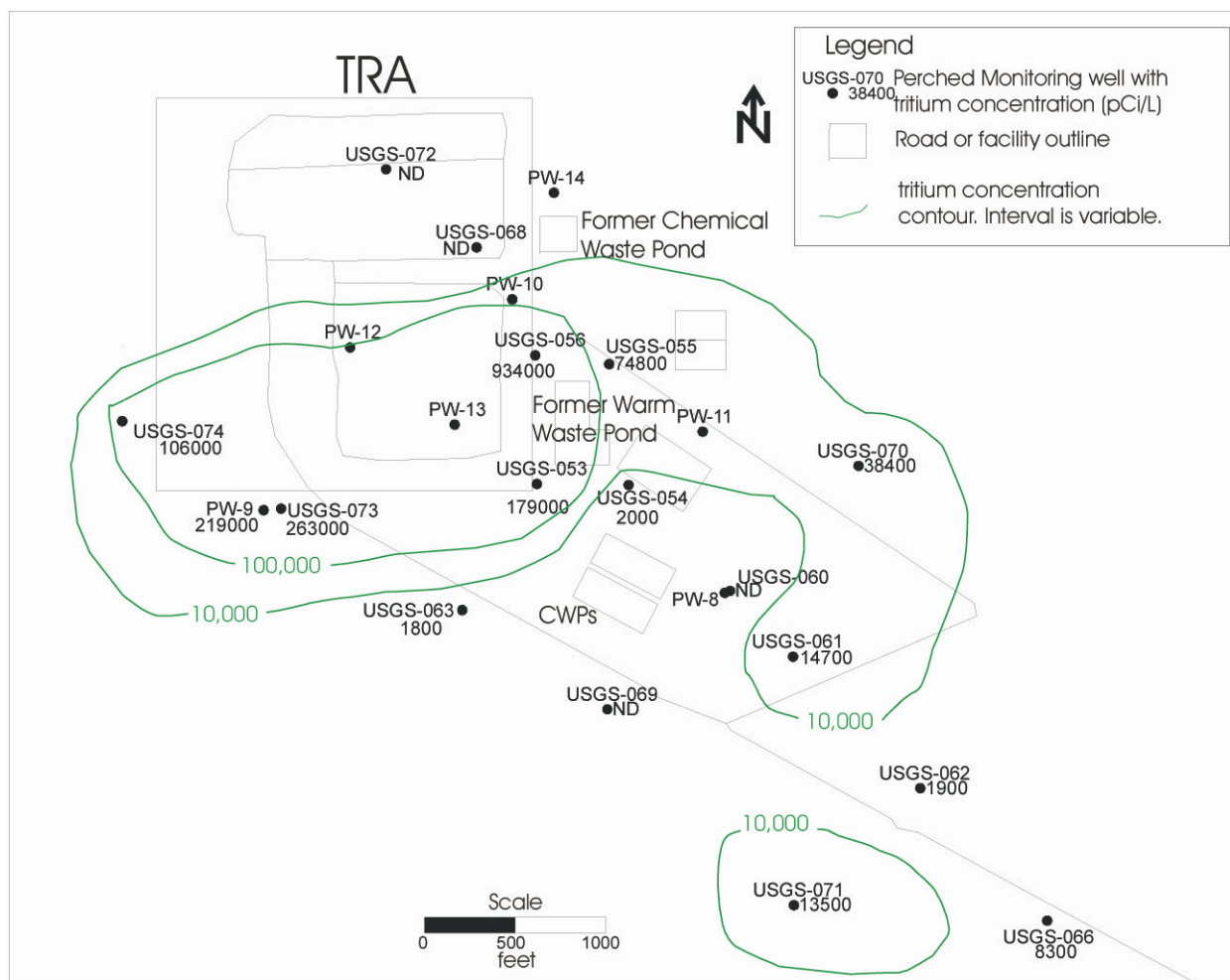


Figure 25. Distribution of tritium in perched water in 1990.

4.1.5 Organics

Seven wells (PW-10, PW-12, PW-13, USGS-053, USGS-073, TRA-1933, and TRA-1934) were sampled for diesel-range organics. The highest concentration for diesel-range organics was 4.7 mg/L in PW-13. The TRA-1933 and TRA-1934 wells had concentrations of diesel-range organics of 0.83 and 1.2 mg/L, respectively. Well PW-13 also was sampled for gasoline-range organics and had a concentration range of 87 to 309 µg/L with the gasoline-range organic results for TRA-1933 and TRA-1934 also falling within this range. Wells PW-13, TRA-1933, and TRA-1934 also were sampled for BTEX. Benzene and toluene were below detection limits in all samples. Xylenes were present at low concentrations (<10 µg/L) in all three wells. Ethylbenzene also was detected in all three at concentrations less than 3 µg/L.

4.2 Aquifer Contaminant Data

Groundwater samples were collected from the TRA-06A, TRA-07, TRA-08, USGS-065, MIDDLE-1823, and USGS-058 aquifer wells in March 2004 as part of this investigation and in coordination with the regular Waste Area Group 2 sampling. Aquifer wells were analyzed for chromium (filtered and unfiltered), Sr-90, gamma isotopes (includes Co-60), tritium, anions, and metals. In addition, Wells TRA-03, TRA-07, TRA-08, USGS-058, and USGS-076 also were analyzed for metals and anions.

The key constituents—chromium, tritium, Sr-90, Co-60, and organics—are summarized in the following subsections. The results for tritium, Sr-90, and chromium in aquifer wells are summarized in Table 3. In addition to the above analytes, TRA-07 and USGS-076 were sampled for diesel-range organics. Diesel-range organics were below detection limits in TRA-07 and USGS-076. The point of compliance in the aquifer, as stated in the OU 2-12 ROD (DOE-ID 1992), is the upper 12.5 ft of the SRPA.

4.2.1 Chromium

Chromium was present at detectable concentrations in all aquifer wells sampled for this investigation and the regular Waste Area Group 2 sampling. Both filtered and unfiltered samples were collected for chromium. With the exception of TRA-03, chromium concentrations were above background concentrations for all aquifer wells; however, the EPA-defined MCL of 100 µg/L was exceeded only in Wells TRA-07 and USGS-065 (Figure 26 and Table 3). The TRA-07 and USGS-065 wells show a decreasing trend in chromium concentrations (Figure 27).

4.2.2 Tritium

Tritium was present in all of the aquifer wells sampled as part of this study, except for TRA-03. Tritium concentrations were below the 20,000-pCi/L MCL in all wells (Table 3). The highest concentration (18,800 pCi/L) of the samples collected in March occurred in TRA-07 (Figure 26).

4.2.3 Strontium-90 and Cobalt-60

Strontium-90 and Co-60 were not detected in any of the aquifer wells sampled in March 2004.

4.3 Water Source/Characterization Data

Water-quality data and stable-isotope ratios (hydrogen, oxygen) were employed to characterize water sources. The relative and absolute concentrations of common cations and anions are water-quality parameters that can be used to distinguish sources of water. The common cations are sodium, potassium, calcium, and magnesium. The common anions are chloride, sulfate, and bicarbonate. A limited amount of complete water quality data sets have been collected for perched water and the water from the SRPA at TRA. This report addresses the two most complete geochemical data sets, which were collected in 1991 and March 2004. These data sets are indicative of the time of sampling and may not reflect conditions at different times of the year or when the Big Lost River flows.

The current sources of water that could cause perched zones at TRA and transport contaminants include the CWP, the sewage treatment lagoons, infiltrating precipitation, and lawn irrigation. There is also a possibility of leakage from current water lines used for fire-protection water, water supply, and steam. In the past, the WWP and the Warm Waste Retention Basins, along with associated piping, were known to leak (DOE-ID 2003). In addition, the Chemical Waste Pond was active until 2001. The sewage lagoons are lined and assumed not to leak. The chemical signature of the water from the remaining current sources can be used to determine the source(s) of water in the perched-water wells. The source of water for the water supply, lawn irrigation, fire-protection water, and steam lines is the SRPA. The TRA-03 water supply well was sampled to provide the chemical composition of these water sources. The composition of water from TRA-03 is nearly identical to that of USGS-121, which is hydraulically upgradient of INTEC and cross gradient to TRA.

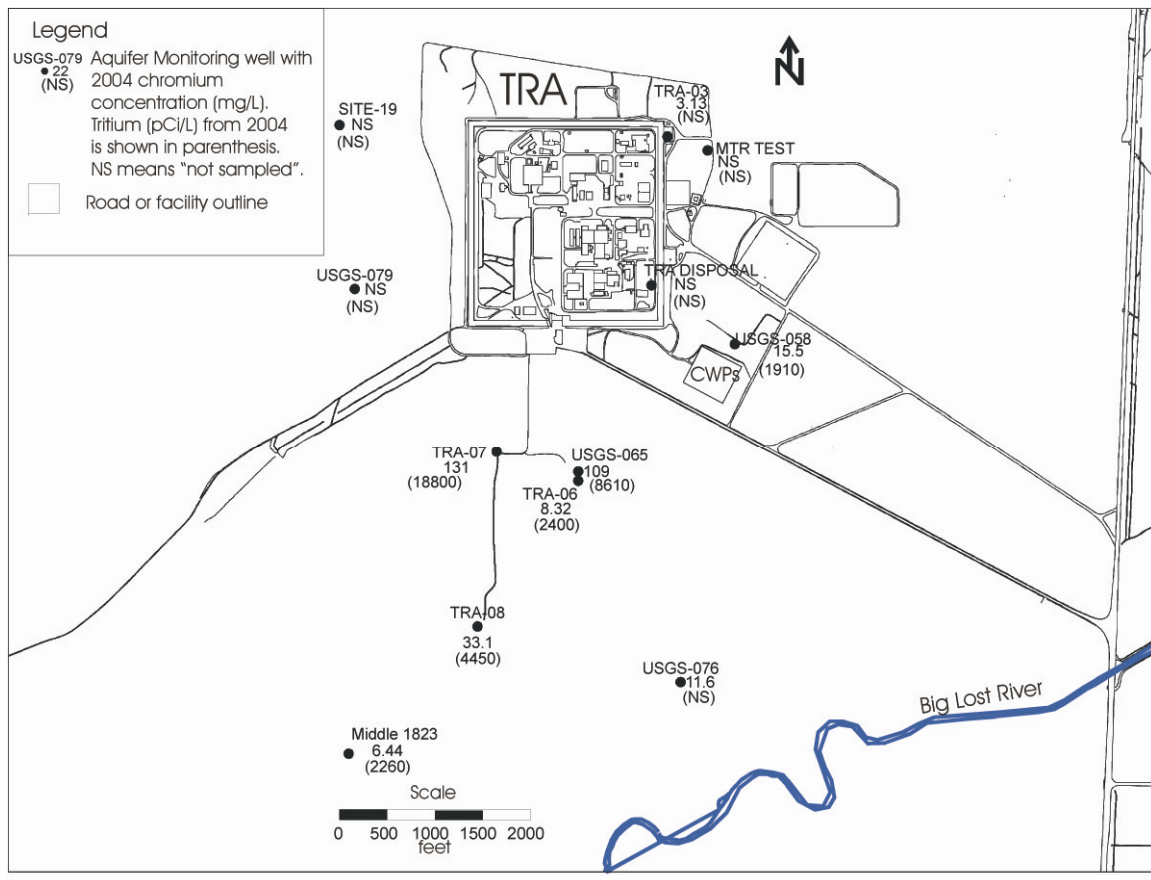


Figure 26. Chromium and tritium concentrations in the Snake River Plain Aquifer at Test Reactor Area in March 2004.

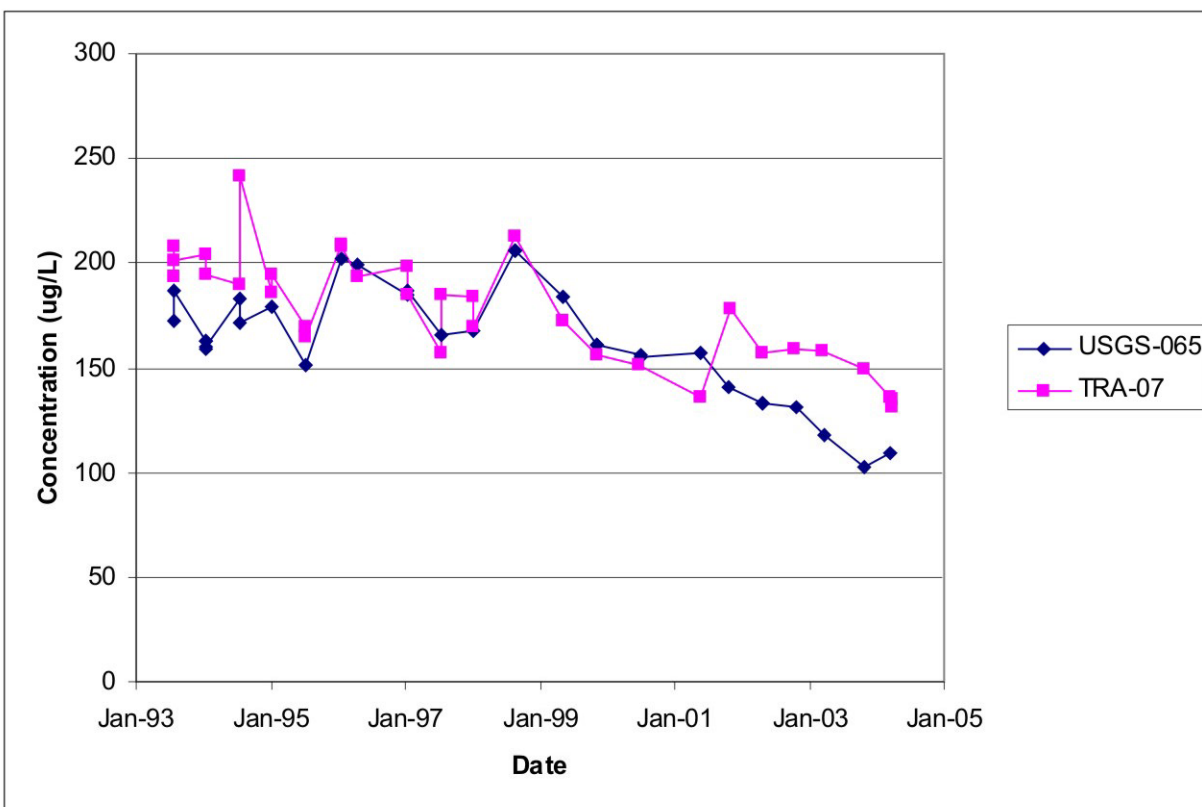


Figure 27. Chromium trends in USGS-065 and TRA-07.

4.3.1 Water-Quality Parameter Data

A Piper diagram was constructed from the 2004 sampling data for major cations and anions (Figure 28). The Piper plot shows that the water discharged into the CWP is enriched in calcium and sulfate while the SRPA water is enriched in calcium and bicarbonate. The effluent to the CWP is distinguished from the SRPA water by its high sulfate content. Because of a lack of complete anion and cation analyses, a value for the effluent to the CWP from 1998 is shown on the Piper diagram, but anion and cation concentrations have varied considerably over time. For instance, sulfate concentrations in effluent to the CWP have varied from 40 to over 400 mg/L. Most wells plot in a trend from the effluent to the CWP to the water-supply well. Unlike wells near the CWP, Wells PW-12 and PW-13 within TRA have anion concentrations that are similar to the water-supply well. Well USGS-068 may have some influence from the CWP, but appears to show influence mostly from the former Chemical Waste Pond. In 2004, Well PW-14 located near the Chemical Waste Pond was dry, probably because of the discontinued use of the pond since 1993. The spatial distribution of the sampled wells and their apparent source influences are shown on Figure 29. Wells that show influence from the CWP include USGS-054, USGS-053, USGS-055, USGS-069, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-069, USGS-070, USGS-073, PW-8, PW-11, CWP-1, and CWP-2. Well CWP-3 indicates a mix of water from the CWP and either precipitation or water from the SRPA (water supply/fire protection). Although a sample is not available, water infiltrating from the surface as a result of precipitation should be a relatively dilute calcium bicarbonate water that is probably similar in composition to the SRPA water, but more dilute.

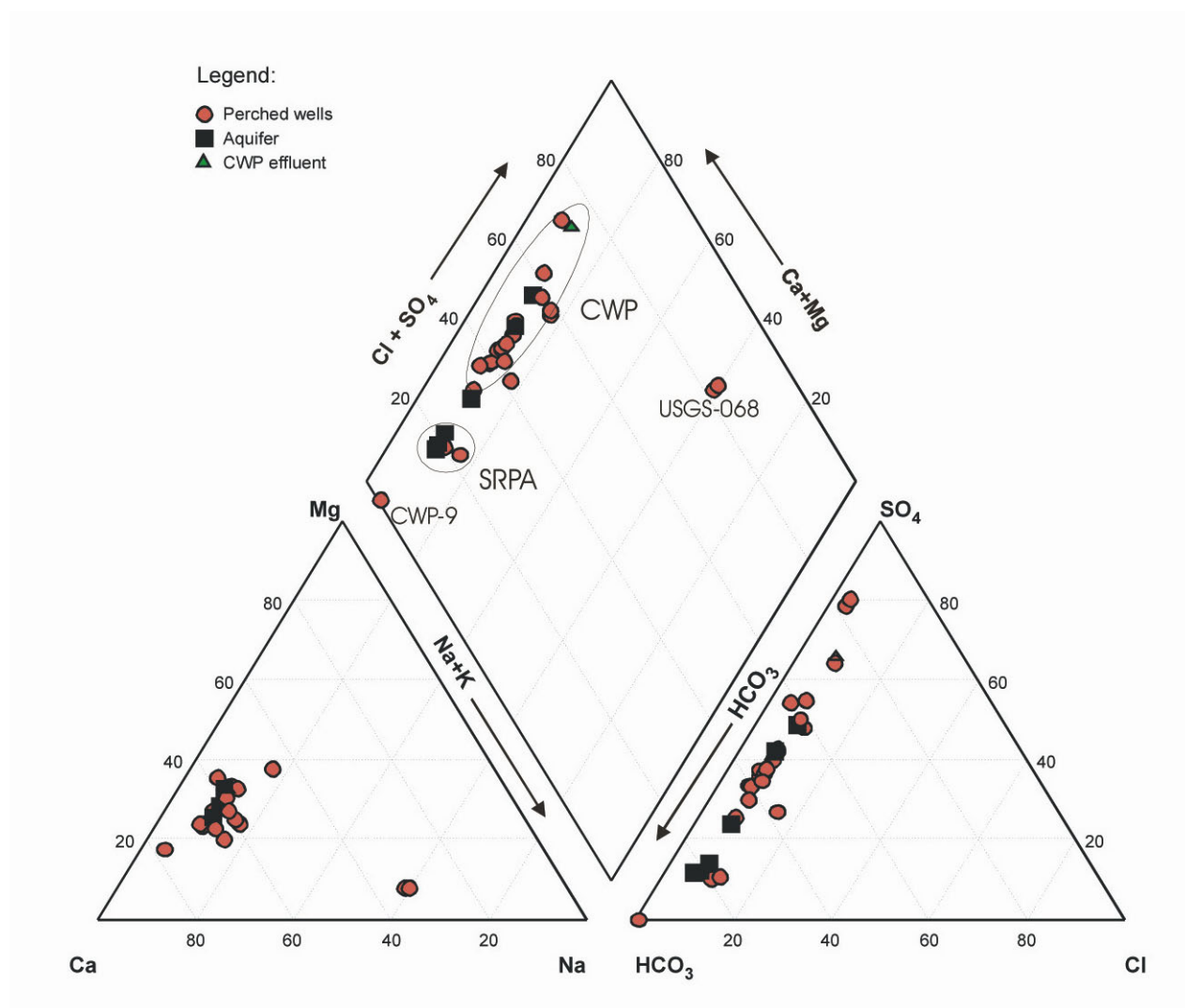


Figure 28. Piper diagram for March 2004 data.

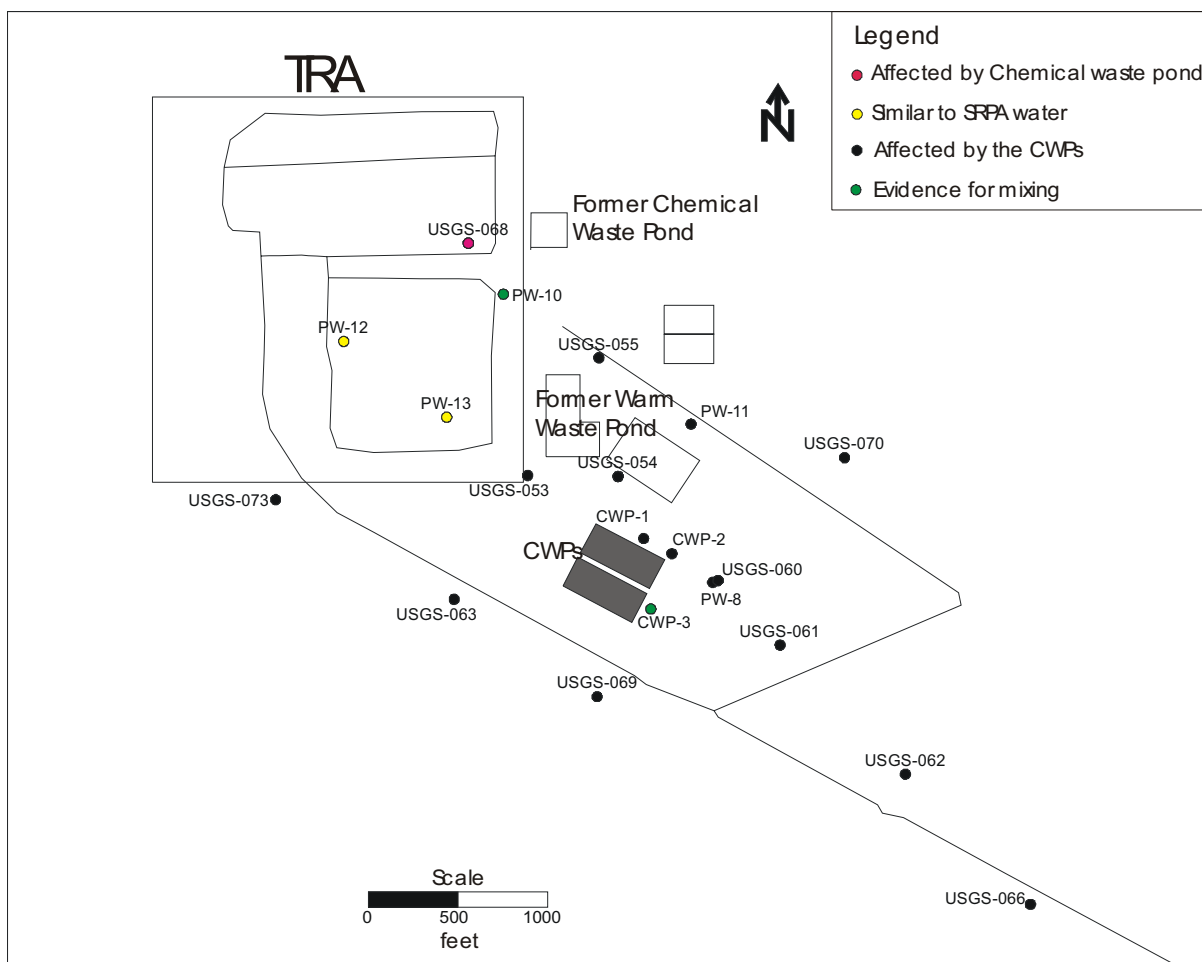


Figure 29. Characterization of perched-water sources for 2004.

(NOTE: The former Chemical Waste Pond and former Warm Waste Pond are no longer in use.)

As an additional note, the cation concentrations in PW-13 were elevated in the 2004 sample, in comparison to the 1991 results. The relative proportion of cations was the same in 2004 as in 1991, and the anion concentrations are similar. Consequently, the PW-13 sample from 2004 plots at the same position on the Piper diagram as the 1991 sample, but the large charge balance error for the 2004 sample would suggest a problem with the cation analysis. The cation results for TRA-1933 and TRA-1934 located near PW-13 are similar to earlier results for PW-13 rather the current data.

A Piper diagram for perched monitoring wells sampled in 1991 also shows that most of the perched-water wells contain water from the CWP (Figure 30). The full analytical results for the 1991 samples are reported in the *Environmental Characterization Report for the Test Reactor Area* (EG&G Idaho 1991a). Most wells plot in a similar position to the samples near the CWP collected in 2004 and the effluent to the CWP from 1998. As seen on Figure 30, the composition of perched water from USGS-68 and PW-14 is considerably different from the water discharged to the CWP. The anion and cation compositions of USGS-068 and PW-14 appear to be influenced by the former Chemical Waste Pond that was operating in 1991. Well USGS-068 may have some water from the CWP, because it plots between PW-14 and the wells near the CWP on Figure 30. Perched-water samples directly under TRA—like PW-12, PW-13, USGS-073, and USGS-072—are primarily calcium bicarbonate waters and

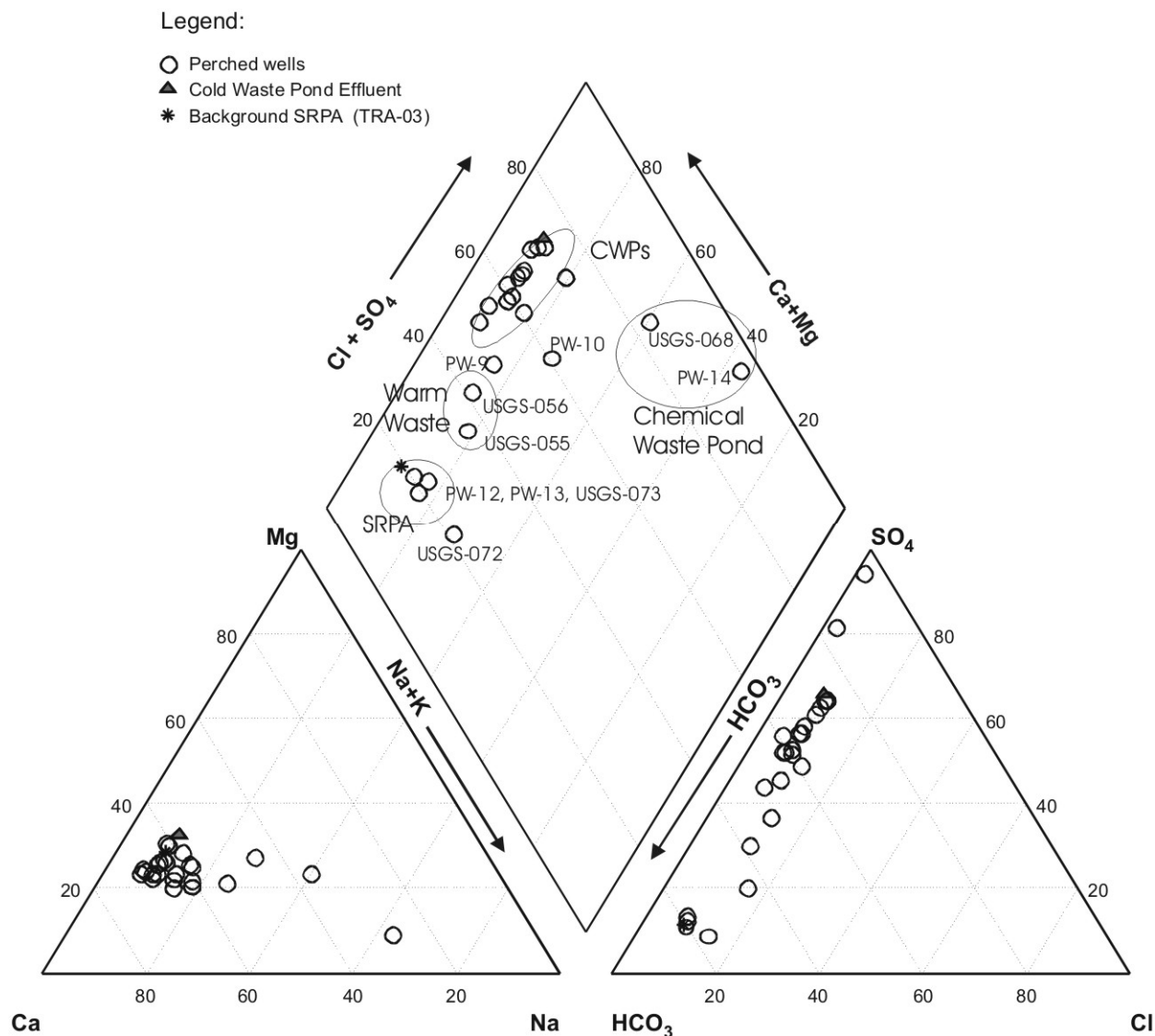


Figure 30. Piper diagram for 1991 perched-water wells.

are similar to water from the SRPA or infiltrating precipitation. Well PW-10 appears to show mixing between water from the Chemical Waste Pond and either the CWP or raw water line leaks.

Wells USGS-055 and USGS-056 appear to show influence from the former WWP. Wells that show influence from the CWP include USGS-054, USGS-053, USGS-069, USGS-060, USGS-061, USGS-062, USGS-063, USGS-066, USGS-069, USGS-070, USGS-071, USGS-074, PW-8, CWP-1, and CWP-2 (Figure 31). Wells PW-9 and PW-11 appear to show mixing between water from the WWP and CWP. In addition to the chemical data, water-level fluctuations in USGS-68, USGS-072, and PW-12 do not respond to the change in flux to the Cold Waste Ponds like wells closer to the CWP, which implies that these wells have a source of water other than the CWP (INEL 1996).

A comparison of the perched-water source characterization plots for 1991 and 2004 suggest that the source of water for some wells has changed over time as water sources (Chemical Waste Pond and WWP/Warm Waste Retention Basins) have been removed (compare Figures 29 and 30). The removal of the sources has probably also led to PW-14 and USGS-056 drying up. The historical influence of the Chemical Waste Pond, WWP, and Warm Waste Retention Basins helps explain why contaminants are

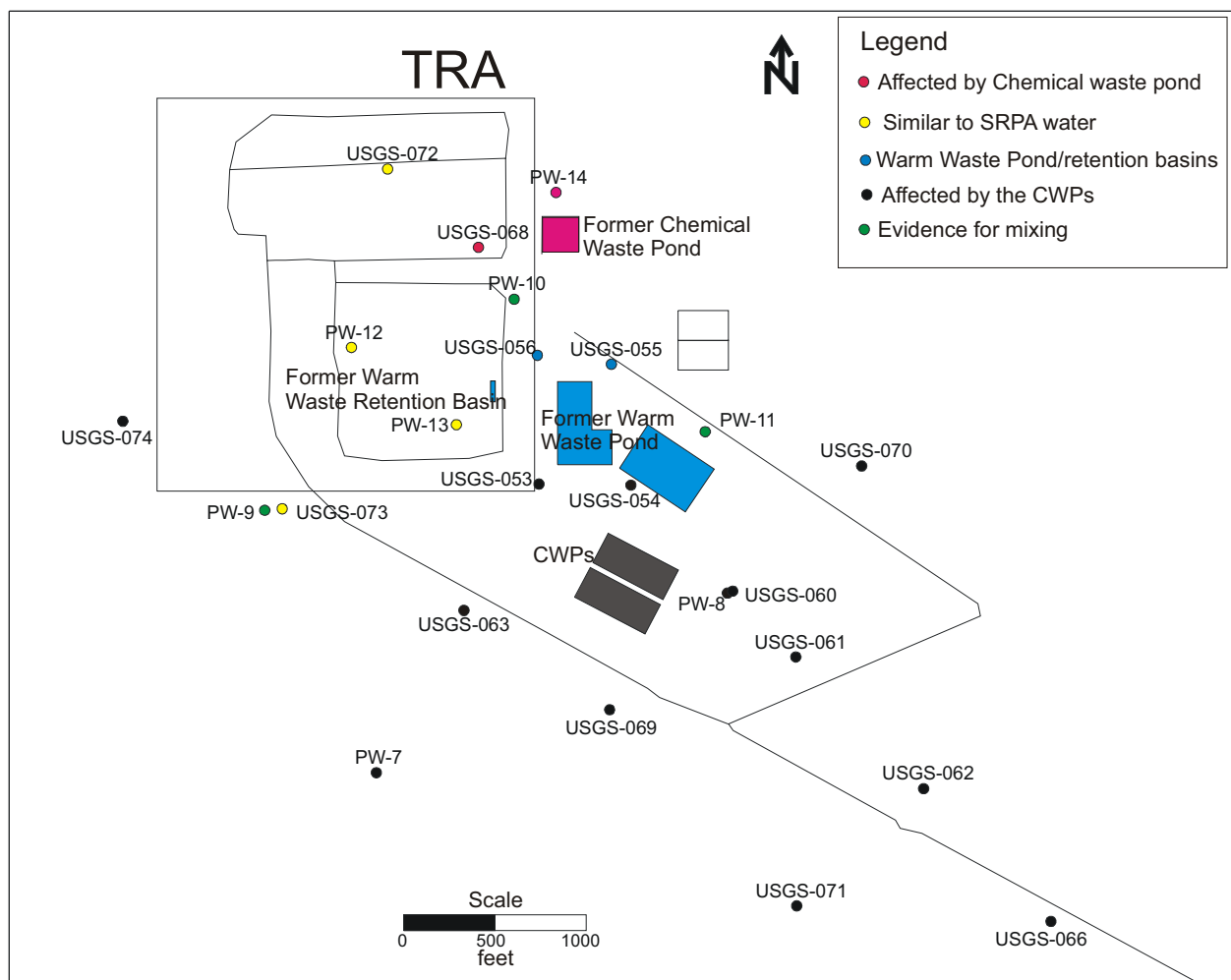


Figure 31. Characterization of perched-water sources for 1991.

still present in some wells today even though the original water source has been replaced in some cases by a different water source. The *Remedial Investigation Report for Test Reactor Area Perched Water System (Operable Unit 2-12)* (Dames and Moore 1992a) contains several figures showing historical contaminant concentrations in the perched water.

4.3.2 Physical Parameter Data

The data for field-measured parameters including temperature, pH, dissolved oxygen, and specific conductance are summarized in Table 4 for perched and aquifer wells. The data for field parameters can be used as indicators of contamination and water-source characteristics. The conductivity values for the aquifer wells in the immediate vicinity of TRA ranged from 0.407 to 0.625 millimhos per centimeter (mmhos/cm). The lowest values are for the upgradient well, TRA-03. The conductivity of most of the perched-water samples also was greater than that of TRA-03. The pH values for SRPA wells ranged from 7.57 to 8.02.

Table 4. Field-measured parameters for March 2004.

Well Name	Date Sampled	Temperature (°C)	pH	Specific Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)
<i>Perched Water</i>					
CWP-1	3/7/2004	13.25	7.64	0.825	NM
CWP-2	3/7/2004	NM	NM	NM	NM
CWP-3	3/3/2004	14.67	8.06	0.466	5.7
CWP-4	3/3/2004	14.11	7.96	0.467	6.96
CWP-8	3/3/2004	17.44	7.91	0.462	5.74
CWP-9	3/2/2004	9.29	7.48	0.097	NM
PW-10	3/17/2004	14.84	7.25	0.847	5.86
PW-11	3/8/2004	16.35	7.79	0.657	6.89
PW-12	3/17/2004	15.61	7.48	0.483	5.13
PW-13	3/17/2004	NM	NM	NM	NM
PW-8	3/9/2004	16.35	7.62	0.606	6.45
USGS-53	3/9/2004	16.97	7.3	0.554	4.02
USGS-54	3/8/2004	16.9	7.54	0.546	6.06
USGS-55	3/8/2004	14.3	7.45	0.553	5.41
USGS-60	3/9/2004	15.15	7.59	0.554	6.64
USGS-61	3/9/2004	13.73	7.73	0.605	6.23
USGS-62	3/10/2004	16.89	7.29	0.626	6.29
USGS-63	3/10/2004	17.58	7.44	0.617	6.34
USGS-66	3/15/2004	12.93	7.57	0.734	6.03
USGS-68	3/17/2004	13.71	7.17	2.82	6.55
USGS-69	3/11/2004	15.41	7.68	0.493	4.63
USGS-70	3/15/2004	13.93	7.61	0.562	6.41
USGS-72	3/21/2004	16	7.29	0.47	2.53
USGS-73	3/10/2004	14.67	8.00	0.562	1.44
<i>Aquifer Wells</i>					
MIDDLE-1823	3/23/2004	15.4	7.57	0.499	5.98
TRA-03	3/15/2004	13.15	7.8	0.407	7.03
TRA-06	3/11/2004	13.29	7.74	0.438	7.1
TRA-07	3/16/2004	12.81	7.86	0.607	7.59
TRA-08	3/25/2004	14.88	8.02	0.439	7.55
TRA-08	3/16/2004	12.94	7.96	0.448	6.98
USGS-58	3/10/2004	13.12	7.79	0.434	7.46
USGS-65	3/11/2004	13.06	7.63	0.625	7.38
USGS-76	3/23/2004	12.61	7.75	0.434	6.97

CWP = Cold Waste Pond

NM = not measured

TRA = Test Reactor Area

USGS = United States Geological Survey

The specific conductance values for the perched-water wells showed a wide range from 0.097 to 2.82 mmhos/cm, but most perched wells were in the range of 0.45 to 0.85 mmhos/cm. The conductivity of the perched-water samples also was greater than that of TRA-03. The pH values for perched wells ranged from 7.17 to 8.00.

4.3.3 Environmental Isotope Data

The sampling activities for this investigation and the regular Waste Area Group 2 sampling activities for March 2004 included the analysis of hydrogen and oxygen isotope ratios from perched and aquifer wells. The stable isotope data were collected to determine source(s) of perched water and to evaluate the flux from the vadose zone into the aquifer. Potential sources of perched water in 2004 include discharge to the CWP, SRPA water leaking from raw water lines, local precipitation (principally snowmelt), and the Big Lost River. Water samples were collected from 29 perched and SRPA wells (Table 5). The conclusions and inferences drawn from the stable isotope study are indicative of the time of sampling in March 2004 and could be different during a different time of the year or when the Big Lost River flows. The analytical methods used to determine the hydrogen and isotope ratios are described in Attachment 2 on the included supplemental data CD.

The stable isotope data for oxygen and hydrogen used in the discussion below are expressed in conventional delta (δ) notation in per mil (‰, parts per thousand) difference in the ratio of the less abundant isotope to the most abundant isotope in a sample relative to the same ratio in a known reference standard (Clark and Fritz 1997). Equation (1) is used:

$$\delta X_{\text{sample}} = [(R_{\text{sample}} - R_{\text{standard}}) / R_{\text{standard}}] \times 1,000 \quad (1)$$

where

δX = the isotope of interest ($\delta^{18}\text{O}$ or δD)

R = the ratio of $^{18}\text{O}/^{16}\text{O}$ or D/H .

The δD results for the perched-water samples ranged from -126.9 to -136.9‰, while the $\delta^{18}\text{O}$ results ranged from -16.1 to -17.9‰. The δD results for the SRPA samples ranged from -131.4 to -137.7‰, while the $\delta^{18}\text{O}$ results ranged from -16.8 to -17.9‰. Most of the perched-water and SRPA samples had $\delta^{18}\text{O}$ values of -17 to -18‰ and δD values of -132 to -137‰.

A plot of $\delta^{18}\text{O}$ and δD values for the perched-water and SRPA samples is shown on Figure 31 along with the global meteoric water line (GMWL) (Craig 1961). The GMWL defines the relationship between $\delta^{18}\text{O}$ and δD values in worldwide fresh waters, but this line is actually a composite of many local or regional meteoric water lines. It is used as a reference, because a local meteoric water line has not yet been determined. The SRPA and perched-water samples plot below and to the right of the GMWL (Figure 32). A best-fit line ($\delta\text{D} = 5.04\delta^{18}\text{O} - 46.5$) through the perched-water and aquifer samples intersects the GMWL at approximate $\delta^{18}\text{O}$ and δD values of -19 and -142, respectively.

Table 5. Oxygen and hydrogen isotope results.

Sample ID	Well	Depth (ft)	δD	$\delta^{18}O$	Sample Date
<i>Perched Water</i>					
TRA 075 01 3A	CWP-1	48.45–59.44	-126.91	-16.1	3/7/2004
TRA 076 01 3A	CWP-2	45.95–52	-132.4	-17.08	3/7/2004
TRA 077 013A	CWP-3	50.16–57	-135.86	-17.72	3/3/2004
TRA 083 013A	CWP-9	34.3–64.45	-133.07	-16.66	3/3/2004
TRA 087 01 3A	PW-10	176.45	-135.82	-17.73	3/17/2004
TRA 178 01 3A	PW-11	109.75	-129.81	-16.68	3/8/2004
TRA 179 01 3A	PW-12	85.4	-135.02	-17.71	3/17/2004
TRA 088 01 3A	PW-13	71.52–89.97	-136.85	-17.94	3/17/2004
TRA 084 01 3A	PW-8	69.55	-132.62	-17.06	3/9/2004
TRA 181 01 3A	USGS-53	70.03	-134.08	-17.41	3/9/2004
TRA 182 01 3A	USGS-54	66.01	-134.81	-17.38	3/8/2004
TRA 183 01 3A	USGS-55	62.1	-134.39	-17.28	3/8/2004
TRA 089 01 3A	USGS-60	68.58	-134.06	-17.24	3/9/2004
TRA 090 01 3A	USGS-61	90.27	-131.35	-16.79	3/9/2004
TRA 091 01 3A	USGS-62	136.57	-133.06	-16.91	3/10/2004
TRA 092 01 3A	USGS-63	76.05	-133.19	-17.06	3/10/2004
TRA 094 01 3A	USGS-66	183.9	-128.33	-16.36	3/15/2004
TRA 095 01 3A	USGS-68	83.74	-130.81	-17.15	3/17/2004
TRA 195 01 3A	USGS-68	83.74	-131.99	-17.1	3/17/2004
TRA 096 01 3A	USGS-69	79.45	-133.35	-17.23	3/11/2004
TRA 097 01 3A	USGS-70	72.86	-133.44	-17.16	3/15/2004
TRA 100 01 3A	USGS-73	87.48	-130.08	-16.68	3/10/2004
<i>Aquifer Wells</i>					
TRA 19101 3A	MIDDLE-1823	720	-136.71	-17.94	3/23/2004
TRA 10801 3A	USGS-76	489.29	-136.77	-17.92	3/23/2004
TRA 190 01 3A	USGS-65		-131.52	-16.78	3/11/2004
TRA 104 01 3A	TRA-03		-137.71	-17.92	3/15/2004
TRA 10501 3A	TRA-07	485.32	-131.41	-16.83	3/25/2004
TRA 10601 3A	TRA-08	489.5	-137.56	-17.84	3/25/2004
TRA 18901 3A	USGS-58	470.14	-136.02	-17.89	3/25/2004
CWP = Cold Waste Pond					
ID = identification					
TRA = Test Reactor Area					
USGS = United States Geological Survey					

The use of SRPA water in industrial processes and irrigation should produce a shift in the $\delta^{18}\text{O}$ and δD values and cause samples to plot to the right of the GMWL. The majority of the perched-water samples show a limited evaporative effect with higher $\delta^{18}\text{O}$ and δD values than water from the SRPA based on the values for TRA-03 (Figure 32). Discharge to the CWP should show seasonal changes with an increase in the $\delta^{18}\text{O}$ and δD values of the effluent in the summer as a result of evaporative effects. In addition, irrigation that is applied to lawns in TRA should also show an increase in $\delta^{18}\text{O}$ and δD values as a result of evaporative effects, unless leaks occurred underground in the irrigation pipes.

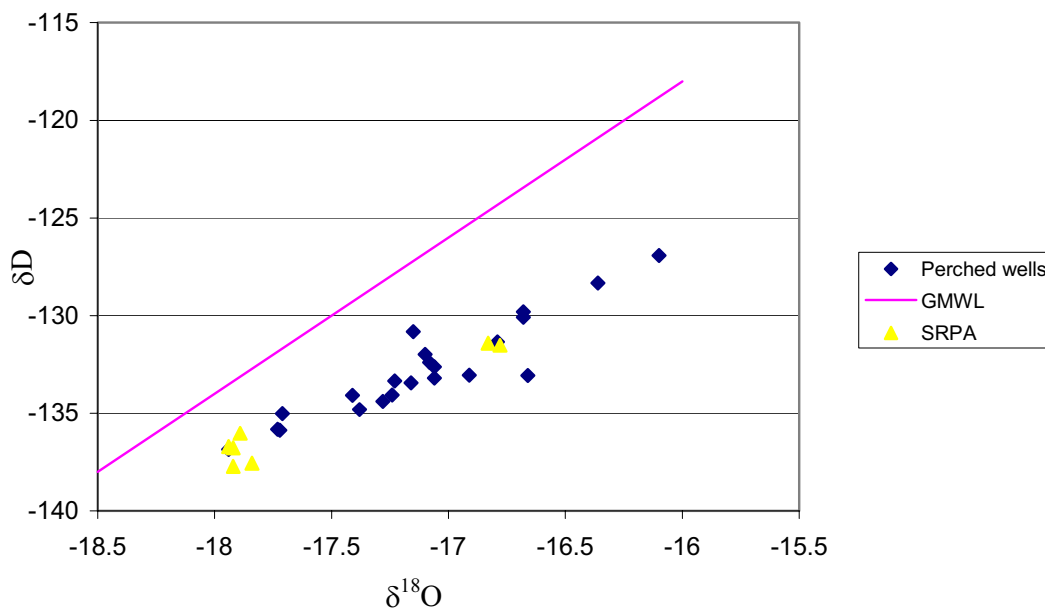


Figure 32. Plot of $\delta^{18}\text{O}$ versus D values for perched water and Snake River Plain Aquifer water.

NOTE: *The global meteoric water line is shown for reference.*

4.4 Discussion of Perched-Water Contamination and Water Sources

This subsection discusses sources of perched water and contamination. The perched-water sources are discussed using primarily data collected in 2004. The principal contaminants in the perched water are Sr-90, tritium, chromium, Co-60, and sulfate, while the principal contaminants in the SRPA are chromium, sulfate, and tritium. Historically, the WWP and retention basins have been a primary source of contamination. The extent of perched-water contamination from the WWP has depended on waste disposal practices and on the variation over time of the quantities of contaminants and discharge water (Dames and Moore 1992a). The extent of the perched zones also has changed as a result of sources of perched water coming online like the CWP in 1982 and the elimination of perched-water sources like the Chemical Waste Ponds.

4.4.1 Discussion of Water Sources Responsible for Perched-Water Bodies

The stable isotope (δD , $\delta^{18}\text{O}$) results and sulfate data for March 2004 suggest that water from the CWP accounts for water in most of the perched-water wells. However, the water-quality and stable-isotope data suggest that the perched water consists of multiple perched-water bodies with different water sources. Sulfate is plotted versus the $\delta^{18}\text{O}$ of the water to integrate the identification of the water

sources with contaminant sources because sulfate concentrations vary considerably for the water sources as seen on the Piper diagrams. The sulfate versus $\delta^{18}\text{O}$ plot shows several groupings of wells corresponding to different water sources (Figure 33). Most wells plot in a grouping that indicates an influence from the CWP. Well CWP-1 does not plot in the group for the CWP on Figure 33; however, CWP-1 does plot with the CWP group on the Piper diagram (Figure 27). This suggests that the source of water for CWP-1 is a more evaporated version of water that is currently discharged to the CWP. Well CWP-1 could be in a slower migration pathway and reflects an averaged yearly $\delta^{18}\text{O}$ and sulfate composition. Although sulfate concentrations in the effluent to the CWP are variable, mixing in the vadose zone should average sulfate concentrations along slower flow paths.

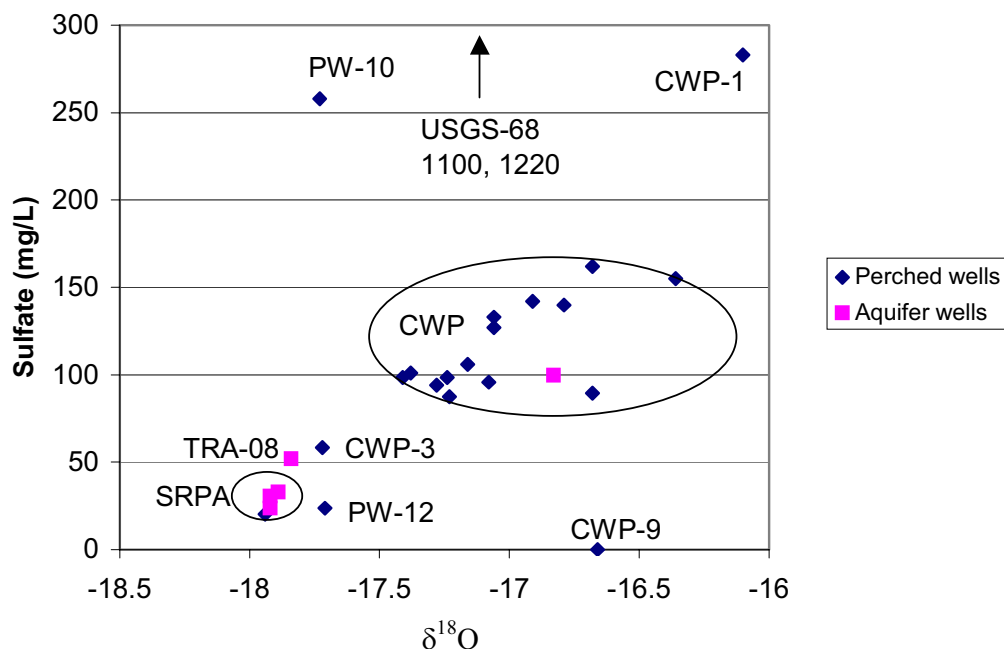


Figure 33. Plot of $\delta^{18}\text{O}$ versus sulfate.

The $\delta^{18}\text{O}$ and δD values in the perched-water wells near the CWP show a general pattern of lower $\delta^{18}\text{O}$ and δD values near the CWP (USGS-054, USGS-053, USGS-60, and USGS-069) and higher $\delta^{18}\text{O}$ and δD values farther away (USGS-066, USGS-062, USGS-061, and USGS-073). This pattern could indicate more rapid flushing of the perched-water wells near the CWP with the wells farther away from the CWP showing a lower flux rate. The higher $\delta^{18}\text{O}$ and δD values in wells farther from the CWP probably reflect an averaging of the water values for multiple seasons. The summer infiltration from the CWP could have higher $\delta^{18}\text{O}$ and δD values as a result of evaporation. In contrast, winter infiltration from the CWP should be shifted only slightly higher than the values for the water supply (i.e., the SRPA).

Three wells (including PW-10, PW-12, and PW-13) are similar in δD and $\delta^{18}\text{O}$ composition to the SRPA water, suggesting that the source of the perched water is from leaking raw water pipes. The water supply for TRA is drawn locally from the SRPA at TRA-03. The stable isotope data for PW-12 have been shifted slightly from SRPA water and this could indicate infiltration from precipitation. In addition, a drainage ditch is located near PW-12. Well PW-10 has a much different anion and cation signature than PW-13 or PW-12, and it plots near the CWP group on the Piper diagram. However, the lower $\delta^{18}\text{O}$ value (similar to the SRPA) for PW-10 suggests a different water source than the CWP. The composition of PW-10 could reflect the influence from the former Chemical Waste Pond. The CWP does not appear to be

the source of water in PW-13, but the occurrence of Sr-90 in Well PW-13 could provide a clue as to the source of water migrating to this well and perhaps the source of diesel as well. The δD and $\delta^{18}O$ along with the sulfate concentration suggests that Wells PW-10, PW-12, and PW-13 intersect perched water bodies that are mostly isolated from the influence of the CWP.

Two wells that plot as isolated points on Figure 33 are CWP-9 and USGS-068. A possible source of water in CWP-9 could be infiltrating precipitation near the CWP, because the sulfate concentration is too low in this well to indicate that the water in this well is from the CWP or SRPA. The source of water in USGS-068 also could be precipitation or leaking facility raw water lines based on the $\delta^{18}O$ value, but the high sulfate concentration would indicate that the infiltration would have to pick up contaminants from the former Chemical Waste Pond along the migration pathway.

Well CWP-3 plots in between the δD and $\delta^{18}O$ range for the SRPA and the values for CWP (Figure 33). The water in CWP-3 could be a mix of CWP and SRPA water, because it lies between these two water sources on Figure 33. However, precipitation cannot be ruled out as a water source for CWP-3.

4.4.2 Discussion of Perched-Water Contamination and Sources

The very distinct geochemical signatures of the different water sources discussed above and the contaminant data in perched-water wells indicate that the deep perched water beneath TRA occurs in stratified or isolated zones with minimal mixing between some zones. This is a departure from the idealized conceptual model presented in Figure 3. Well coverage, both laterally and vertically, is insufficient to completely characterize these zones. Some water-level data indicate that the hydraulic head differences between zones are distinct over short distances. The heterogeneous fractured basalt and discontinuous sediment layers coupled with multiple water sources undoubtedly create these zones. This subsection presents and discusses the limited data that support the premise of multiple, distinct zones forming the deep perched water beneath TRA.

The distribution of tritium in the perched water in 2004 and in 1990 indicates a source of contamination to the northwest of the CWP (Figures 22 through 25). Although USGS-053 was used as an injection well in the early 1960s, the only identified sources of tritium since then are the former WWP and Warm Waste Retention Basins or piping and sumps associated with these facilities. Historically, USGS-056 has had some very high tritium concentrations (956,000 pCi/L), but that well has dried up after the former WWP and Warm Waste Retention Basins were removed from service. The influence of the WWP and Warm Waste Retention Basins extended below the current CWP and southeast to USGS-066 and west under TRA to USGS-074 prior to the initiation of discharge to the CWP in 1982 (Dames and Moore 1992a).

In 1990, tritium was detected in wells that occur in an arc pattern around the CWP (Figure 24). In 2004, the distribution of tritium was similar to that in 1990, but the tritium concentrations had decreased significantly (Figure 25). The decrease in tritium concentrations was greater than that expected from radioactive decay alone (half-life of 12.3 years). For example, the observed decrease in tritium concentration in USGS-055 from 74,800 to 13,000 pCi/L was considerably more than the decrease to approximately 34,000 pCi/L calculated for radioactive decay alone. This tritium pattern indicates that the flux of water in the immediate vicinity of the CWP flushes the perched system fairly rapidly near the CWP, but the flux is much lower further out from the CWP. This pattern of water flux also is suggested by oxygen and hydrogen isotope data, as discussed in the previous section.

The historical occurrence of high tritium concentrations in the USGS-074 and PW-9 perched-water wells, but not in PW-12 or PW-13 located between USGS-074 and PW-9 and the most likely source (WWP/Warm Waste Retention Basins), suggests that the deep perched water is not continuous. Separate